

REPORT

OF THE

THIRTY-FIFTH MEETING

OF THE



BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

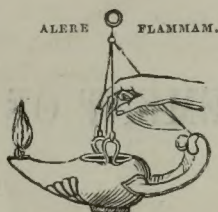
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LONDON:

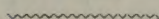
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ERRATA.

In the present volume.

Reports, page 72. *Column 7. Position, &c. :—*

17th line from bottom, for *b* read *c*.

13th ,, ,, for ζ read ρ .

11th ,, ,, for ι read τ .

6th ,, ,, for 30° read 3° .

5th ,, ,, for S. of Cassiopeiæ read S. of α Cassiopeiæ.

Sections, page 62, line 1. for *Glyptolepis* beds read *Caithness Flags*.

In the volume for 1864.

Sections, page 20, 17 lines from bottom, for *The time the sound takes*
read *The time the electric current takes*.

Sections, page 188, line 1, for 0.5 read 0.05.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

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New Life Members who have paid Ten Pounds as a composition.

Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

Annual Members who have intermitted their Annual Subscription.

Associates for the year. [Privilege confined to the volume for that year only.]

3 Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than 100 copies remain*, at one-third of the Publication Price. Application to be made (by letter) to Messrs. Taylor & Francis, Red Lion Court, Fleet St., London.

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.

2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.

3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.

4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.

5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the Meeting of the year by the President and General Secretaries.

6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex-officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee, unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.		VICE-PRESIDENTS.		LOCAL SECRETARIES.	
The EARL FITZWILLIAM, D.C.L., YORK, September 27, 1831.	F.R.S., F.G.S., &c.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	Rev. W. Whewell, F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.	
The REV. W. BUCKLAND, D.D., OXFORD, June 19, 1832.	F.R.S., F.G.S., &c.	Sir David Brewster, F.R.S. L. & E., &c.	Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c.	
The REV. ADAM SEDGWICK, M.A., CAMBRIDGE, June 25, 1833.	V.P.R.S., V.P.G.S.	G. B. Airy, F.R.S., Astronomer Royal, &c.	John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.	
SIR T. MACDOUGALL BRISBANE, K.C.B., EDINBURGH, September 8, 1834.	D.C.L.,	Sir David Brewster, F.R.S., &c.	Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.	
The REV. PROVOST LLOYD, LL.D., DUBLIN, August 10, 1835.	LL.D.	Viscount Oxmantown, F.R.S., F.R.A.S.	Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.	
The MARQUIS OF LANSDOWNE, D.C.L., BRISTOL, August 22, 1836.	F.R.S., &c.	The Marquis of Northampton, F.R.S.	Rev. W. D. Conybeare, F.R.S., F.G.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.	
The EARL OF BURLINGTON, F.R.S., cellar of the University of London	F.G.S., Chan-	The Bishop of Norwich, P.L.S., F.G.S.	Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S.	Professor Traill, M.D.	Wm. Wallace Currie, Esq.
LIVERPOOL, September 11, 1837.		Rev. W. Whewell, F.R.S.	Rev. W. Whewell, F.R.S.	Joseph N. Walker, Pres. Royal Institution, Liver-	pool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c., NEWCASTLE-ON-TYNE, August 20, 1838.	F.R.S., F.G.S., &c.	The Rev. W. Vernon Harcourt, F.R.S., &c.	Prideaux John Selly, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S.	
The REV. W. VERNON HARCOURT, M.A., BIRMINGHAM, August 26, 1839.	F.R.S., &c.	Marquis of Northampton.	Earl of Dartmouth.	George Barker, Esq., F.R.S. Peyton Blakiston, M.D.	
The MARQUIS OF BREADALBANE, F.R.S.		The Rev. T. R. Robinson, D.D.	John Currie, Esq., F.R.S.	Joseph Hodgson, Esq., F.R.S.	Follett Osler, Esq.
GLASGOW, September 17, 1840.		Sir T. M. Brisbane, Bart., F.R.S.	The Earl of Mount Edgumbe.	Andrew Liddell, Esq.	Rev. J. P. Nicol, LL.D.
The REV. PROFESSOR WHEWELL, F.R.S., &c.		The Earl of Morley.	Lord Eliot, M.P.	W. Snow Harris, Esq., F.R.S.	
PLYMOUTH, July 29, 1841.		Sir C. Lemon, Bart.	Sir D. T. Acland, Bart.	Col. Hamilton Smith, F.L.S.	
The LORD FRANCIS EGERTON, F.G.S., MANCHESTER, June 23, 1842.		John Dalton, D.C.L., F.R.S.	Hon. and Rev. W. Herbert, F.L.S., &c.	Robert Were Fox, Esq.	Richard Taylor, jun., Esq.
		Rev. A. Sedgwick, M.A., F.R.S.	W. C. Henry, M.D., F.R.S.	Peter Clare, Esq., F.R.A.S.	
		Sir Benjamin Heywood, Bart.		W. Fleming, M.D.	
				James Heywood, Esq., F.R.S.	
The EARL OF ROSSE, F.R.S., DUBLIN, August 17, 1843.		Viscount Adare		Professor John Stevelly, M.A.	
		Sir W. R. Hamilton, Pres. R.I.A.		Rev. Jos. Carson, F.R.C. Dublin.	
		Rev. T. R. Robinson, D.D.		William Kelecher, Esq.	Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S..... York, September 26, 1844.	{ Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S. }	{ William Hatfield, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq. }
SIR JOHN F. W. HERSCHHEL, Bart., F.R.S., &c..... CAMBRIDGE, June 19, 1845.	{ The Earl of Hardwicke. The Bishop of Norwich..... Rev. J. Graham, D.D. Rev. G. Ansie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S. }	{ William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S. Henry Clark, M.D. T. H. C. Moody, Esq. }
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	{ The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S. }	{ Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M. Matthew Moggridge, Esq. D. Nicol, M.D. }
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	{ The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University D.C.L., M.P. for the University of Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S. }	{ Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq. }
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	{ The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. Delabecque, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's.... }	{ Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E. }
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S., BIRMINGHAM, September 12, 1849.	{ The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S. }	{ Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E. }
SIR DAVID BREWSTER, K.H., LL.D., F.R.S.L. & E., Principal of the United College of St. Salvador and St. Leonard, St. Andrews..... EDINBURGH, July 21, 1850.	{ Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S., F.R.S. The Earl of Rosbery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brishane, Bart., D.C.L., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E. }	{ Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E. }

LOCAL SECRETARIES.

VICE-PRESIDENTS.

PRESIDENTS.

GEORGE BIDDLE AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boleau, Bart., F.R.S. Sir William F.F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. Delabèche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast. Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. & Philos. Society. William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull. Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart. M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfalan, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S.L. & F. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint. Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Professor Thomas Anderson, M.D. William Goulie, Esq.
CHARLES G. B. DAUBENTY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Rodenick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E. V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Nelson Hancock, LL.D.

RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S.,
 Superintendent of the Natural History Departments of
 the British Museum
 LEEDS, September 22, 1858.

HIS ROYAL HIGHNESS THE PRINCE CONSORT ..
 ABERDEEN, September 14, 1859.

The LORD WROTTESELEY, M.A., V.P.R.S., F.R.A.S.
 OXFORD, June 27, 1860.

WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S.
 MANCHESTER, September 4, 1861.

The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor
 of Natural and Experimental Philosophy in the Univer-
 sity of Cambridge
 CAMBRIDGE, October 1, 1862.

The Lord Monteaigle, F.R.S.
 The Lord Viscount Goderich, M.P., F.R.G.S.
 The Right Hon. M. T. Baines, M.A., M.P.
 Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S.
 The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S.,
 Master of Trinity College, Cambridge
 James Garth Marshall, Esq., M.A., F.G.S.
 R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.

The Duke of Richmond, K.G., F.R.S.
 The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S.
 The Lord Provost of the City of Aberdeen
 Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S.
 Sir David Brewster, K.H., D.C.L., F.R.S.
 Sir Rodenick I. Murchison, G.C.St.S., D.C.L., F.R.S.
 The Rev. W. V. Harcourt, M.A., F.R.S.
 The Rev. T. R. Robinson, D.D., F.R.S.
 A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen.

The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford ...
 The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford ...
 The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire ...
 The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S.
 The Lord Bishop of Oxford, D.D., F.R.S.
 The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford
 Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S.
 Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.

The Earl of Ellesmere, F.R.G.S.
 The Lord Stanley, M.P., D.C.L., F.R.G.S.
 The Lord Bishop of Manchester, D.D., F.R.S., F.G.S.
 Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S.
 Sir Benjamin Heywood, Bart., F.R.S.
 Thomas Bazley, Esq., M.P.
 James Aspinall Turner, Esq., M.P.
 James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Man-
 chester.
 Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E.
 Joseph Whitworth, Esq., F.R.S., M.I.C.E.

The Rev. the Vice-Chancellor of the University of Cambridge
 The Very Rev. Harvey Goodwin, D.D., Dean of Ely.
 The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge
 The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S.
 Rev. J. Challis, M.A., F.R.S.
 G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal
 Professor G. G. Stokes, M.A., D.C.L., F.R.S., Sec. R.S.
 Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.

Rev. Thomas Hincks, B.A.
 W. Sykes Ward, Esq., F.C.S.
 Thomas Wilson, Esq., M.A.

Professor J. Nicol, F.R.S.E., F.G.S.
 Professor Fuller, M.A.
 John F. White, Esq.

George Rolleston, M.D., F.L.S.
 H. J. S. Smith, Esq., M.A., F.C.S.
 George Griffith, Esq., M.A., F.C.S.

R. D. Darbishire, Esq., B.A., F.G.S.
 Alfred Nield, Esq.
 Arthur Ransome, M.A., Esq.
 Professor H. E. Roscoe, B.A.

Professor C. C. Dabington, M.A., F.R.S., F.L.S.
 Professor G. D. Liveing, M.A.
 The Rev. N. M. Ferrers, M.A.

PRESIDENTS.

SIR W ARMSTRONG, C.B., LL.D., F.R.S.,.....
NEWCASTLE-ON-TYNE, August 26, 1863.

SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. ..
BATH, September 14, 1861.

JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S.,
Professor of Geology in the University of Oxford
BIRMINGHAM, September 6, 1865.

WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S.
NOTTINGHAM, August 22, 1866.

VICE-PRESIDENTS.

Sir Walter C. Trevelyan, Bart., M.A.
Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S.
Hugh Taylor, Esq., Chairman of the Coal Trade
Isaac Lowthian Bell, Esq., Mayor of Newcastle.
Nicholas Wood, Esq., President of the Northern Institute of Mining En-
gineers
Rev. Temple Chevallier, B.D., F.R.A.S.
William Fairbairn, Esq., LL.D., F.R.S.

The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somers-
etshire
The Most Noble the Marquis of Bath
The Right Hon. Earl Nelson
The Lord Portman
The Very Reverend the Dean of Hereford
The Venerable the Archdeacon of Bath
W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A.
A. E. Way, Esq., M.P.
Francis H. Dickinson, Esq.
W. Sanders, Esq., F.R.S., F.G.S.

The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire. .
The Right Hon. the Earl of Dudley
The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire
The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire ...
The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S.
The Right Reverend the Lord Bishop of Worcester
The Right Hon. C. B. Adderley, M.P.
William Scholerfeld, Esq., M.P. .. | F. Osier, Esq., F.R.S.
J. T. Chance, Esq. | The Rev. Charles Evans, M.A. ..

His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire
His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire
The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire
The Right Hon. J. E. Denison, M.P.
J. C. Webb, Esq., High-Sheriff of Nottinghamshire
Thomas Graham, Esq., F.R.S., Master of the Mint
Joseph Hooker, M.D., F.R.S., F.L.S.
John Russell Hinds, Esq., F.R.S., F.R.A.S.
T. Close, Esq.

LOCAL SECRETARIES.

A. Noble, Esq.
Augustus H. Hunt, Esq.
R. C. Clapham, Esq.

C. Moore, Esq., F.G.S.
C. E. Davis, Esq.
The Rev. H. H. Winwood, M.A.

William Mathews, Esq., jun., F.G.S.
John Henry Chamberlain, Esq.
The Rev. G. D. Boyle, M.A.

Dr. Robertson.
Edward J. Lowe, Esq., F.R.A.S., F.L.S.
The Rev. J. F. McCallan, M.A.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from September 14, 1864 (commencement of BATH MEETING) to September 6, 1865 (BIRMINGHAM).

RECEIPTS.

To Balance brought from last Account	£	s.	d.
Received for Life Compositions at Bath and since	364	17	5
" Annual Subscriptions, ditto ditto	456	0	0
" Associates' Tickets, ditto ditto	502	1	0
" Ladies' Tickets, ditto ditto	1116	0	0
" Dividends on Stock, 1 year.....	1055	0	0
" Sale of Publications—viz.	249	13	9
Reports.....	28	7	6
Index, Catalogue of Stars, &c.	52	9	5
of Dr. J. Blake, being Balance of Grants made in 1844. and 1846 to Committee on Action of Medicines	80	16	11
	7	10	0

PAYMENTS.

By paid Expenses of Bath Meeting, Sundry Printing, Binding, Advertising, and Incidental Petty Expenses by the General Treasurer and Local Treasurers	£	s.	d.
Paid for Printing, Engraving, and Binding Report of 33rd Meeting (Newcastle)	294	16	2
For Salaries, 12 months	836	12	7
On account of Grants made at Bath Meeting, viz. —	350	0	0
For Maintaining Establishment of Kew Observatory...	£600	0	0
Balloon Committee	100	0	0
Committee on Hydroidea.....	13	0	0
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
" Hexelic Compounds.....	20	0	0
" Amyl Compounds.....	20	0	0
" Irish Flora	25	0	0
" American Mollusca	3	9	0
" Organic Acids.....	20	0	0
" Lingula Flags Excavation	10	0	0
" Eurypteris	50	0	0
" Electrical Standards	100	0	0
" Malta Caves Researches	30	0	0
" Oyster Breeding.....	25	0	0
" Gibraltar Caves Researches	150	0	0
" Kent's Hole Excavations.....	100	0	0
" Moon's Surface Observations	35	0	0
" Marine Fauna	25	0	0
" Dredging Aberdeenshire	25	0	0
" Do. Channel Islands.....	50	0	0
" Zoological Nomenclature	5	0	0
" Resistance of Floating Bodies in Water	100	0	0
" Bath Waters Analysis	8	10	10
" Luminous Meteors	40	0	0
	1591	7	10
Balance at London and Westminster Bank ...	£740	8	9
" in hands of General Treasurer	18	13	9
	759	2	6
	£3831	19	1

II. Table showing the Names of Members of the British Association who have served on the Council in former years.

Aberdeen, Earl of, LL.D., K.G., K.T., F.R.S. (deceased).	Brunel, Sir M. I., F.R.S. (deceased).
Acland, Sir T. D., Bart., M.A., D.C.L., F.R.S.	Buckland, Very Rev. William, D.D., F.R.S., Dean of Westminster (deceased).
Acland, Professor H. W., M.D., F.R.S.	Bute, John, Marquis of, K.T. (deceased).
Adams, Prof. J. Couch, M.A., D.C.L., F.R.S.	Carlisle, G. W. Fred., Earl of, F.R.S. (dec ^d).
Adamson, John, Esq., F.L.S.	Carson, Rev. Joseph, F.T.C.D.
Adderley, The Right Hon. C.B., M.P.	Cathcart, Lt.-Gen., Earl of, K.C.B., F.R.S.E. (deceased).
Ainslie, Rev. Gilbert, D.D., Master of Pembroke Hall, Cambridge.	Challis, Rev. J., M.A., F.R.S.
Airy, G. B., M.A., D.C.L., F.R.S., Astr. Royal.	Chalmers, Rev. T., D.D. (deceased).
Alison, Professor W. P., M.D., F.R.S.E. (dec ^d).	Chance, James, Esq.
Allen, W. J. C., Esq.	Chance, J. T., Esq.
Anderson, Prof. Thomas, M.D.	Chester, John Graham, D.D., Lord Bishop of (deceased).
Ansted, Professor D. T., M.A., F.R.S.	Chevallier, Rev. Temple, B.D., F.R.A.S.
Argyll, G. Douglas, Duke of, F.R.S. L. & E.	Christie, Professor S. H., M.A., F.R.S. (dec ^d).
Armstrong, Sir W. G., F.R.S.	Clapham, R. C., Esq.
Arnott, Neil, M.D., F.R.S.	Clare, Peter, Esq., F.R.A.S. (deceased).
Ashburton, William Bingham, Lord, D.C.L. (deceased).	Clark, Rev. Prof., M.D., F.R.S. (Cambridge.)
Atkinson, Rt. Hon. R., late Lord Mayor of Dublin.	Clark, Henry, M.D.
Babbage, Charles, Esq., M.A., F.R.S.	Clark, G. T., Esq.
Babington, Professor C. C., M.A., F.R.S.	Clear, William, Esq. (deceased).
Baily, Francis, Esq., F.R.S. (deceased).	Clerke, Major S., K.H., R.E., F.R.S. (dec ^d).
Baines, Rt. Hon. M. T., M.A., M.P. (dec ^d).	Clift, William, Esq., F.R.S. (deceased).
Baker, Thomas Barwick Lloyd, Esq.	Close, Very Rev. F., M.A., Dean of Carlisle.
Balfour, Professor John H., M.D., F.R.S.	Cobbold, John Chevalier, Esq., M.P.
Barker, George, Esq., F.R.S. (deceased).	Colquhoun, J. C., Esq., M.P. (deceased).
Bath, The Most Noble the Marquis of.	Conybeare, Very Rev. W. D., Dean of Llandaff (deceased).
Bath, The Venerable the Archdeacon of.	Cooper, Sir Henry, M.D.
Beamish, Richard, Esq., F.R.S.	Cork and Orrery, The Rt. Hon. the Earl of, Lord-Lieutenant of Somersetshire.
Beechey, Rear-Admiral, F.R.S. (deceased).	Corrie, John, Esq., F.R.S. (deceased).
Bell, Isaac Lowthian, Esq.	Crum, Walter, Esq., F.R.S.
Bell, Professor Thomas, V.P.L.S., F.R.S.	Currie, William Wallace, Esq. (deceased).
Bengough, George, Esq.	Dalton, John, D.C.L., F.R.S. (deceased).
Bentham, George, Esq., Pres. L.S.	Daniell, Professor J. F., F.R.S. (deceased).
Biddell, George Arthur, Esq.	Darbishire, R. D., Esq., B.A., F.G.S.
Bigge, Charles, Esq.	Dartmouth, William, Earl of, D.C.L., F.R.S.
Blakiston, Peyton, M.D., F.R.S.	Darwin, Charles, Esq., M.A., F.R.S.
Boileau, Sir John P., Bart., F.R.S.	Daubeny, Prof. C. G. B., M.D., LL.D., F.R.S.
Boyle, Right Hon. D., Lord Justice-General (deceased).	DelaBeche, Sir H. T., C.B., F.R.S., Director-Gen. Geol. Surv. United Kingdom (dec ^d).
Brady, The Rt. Hon. Maziere, M.R.I.A., Lord Chancellor of Ireland.	De la Rue, Warren, Ph.D., F.R.S.
Brand, William, Esq.	Derby, Earl of, D.C.L., Chancellor of the University of Oxford.
Breadalbane, John, Marquis of, K.T., F.R.S. (deceased).	Dévonshire, W., Duke of, M.A., D.C.L., F.R.S.
Brewster, Sir David, K.H., D.C.L., LL.D., F.R.S. L. & E., Principal of the University of Edinburgh.	Dickinson, Francis H., Esq.
Brisbane, General Sir Thomas M., Bart., K.C.B., G.C.H., D.C.L., F.R.S. (dec ^d).	Dickinson, Joseph, M.D., F.R.S.
Brodie, Sir B. C., Bart., D.C.L., P.R.S. (deceased).	Dillywyn, Lewis W., Esq., F.R.S. (deceased).
Brooke, Charles, B.A., F.R.S.	Donkin, Professor W. F., M.A., F.R.S.
Brown, Robert, D.C.L., F.R.S. (deceased).	Drinkwater, J. E., Esq. (deceased).
	Ducie, The Earl of, F.R.S.
	Dudley, The Right Hon. the Earl of.
	Dunraven, The Earl of, F.R.S.
	Egerton, Sir P. de M. Grey, Bart., M.P., F.R.S.

- Eliot, Lord, M.P.
 Ellesmere, Francis, Earl of, F.G.S. (dec^d).
 Enniskillen, William, Earl of, D.C.L., F.R.S.
 Estcourt, T. G. B., D.C.L. (deceased).
 Evans, The Rev. Charles, M.A.
 Fairbairn, William, LL.D., C.E., F.R.S.
 Faraday, Professor, D.C.L., F.R.S.
 Ferrers, Rev. N. M., M.A.
 FitzRoy, Rear-Admiral, F.R.S. (deceased).
 Fitzwilliam, The Earl, D.C.L., F.R.S. (dec^d).
 Fleming, W., M.D.
 Fletcher, Bell, M.D.
 Foote, Lundy E., Esq.
 Forbes, Charles, Esq. (deceased).
 Forbes, Prof. Edward, F.R.S. (deceased).
 Forbes, Prof. J. D., LL.D., F.R.S., Sec. R.S.E.,
 Principal of University of St. Andrews.
 Fox, Robert Were, Esq., F.R.S.
 Frost, Charles, F.S.A.
 Fuller, Professor, M.A.
 Galton, Francis, F.R.S., F.G.S.
 Gassiot, John P., Esq., F.R.S.
 Gilbert, Davies, D.C.L., F.R.S. (deceased).
 Gladstone, J. H., Ph.D., F.R.S.
 Goodwin, The Very Rev. H., D.D., Dean of
 Ely.
 Gourlie, William, Esq. (deceased).
 Graham, T., M.A., D.C.L., F.R.S., Master of
 the Mint.
 Gray, John E., Esq., Ph.D., F.R.S.
 Gray, Jonathan, Esq. (deceased).
 Gray, William, Esq., F.G.S.
 Green, Prof. Joseph Henry, D.C.L., F.R.S.
 (deceased).
 Greenough, G. B., Esq., F.R.S. (deceased).
 Griffith, George, M.A., F.C.S.
 Griffith, Sir R. Griffith, Bt., LL.D., M.R.I.A.
 Grove, W. R., Esq., M.A., F.R.S.
 Hallam, Henry, Esq., M.A., F.R.S. (dec^d).
 Hamilton, W. J., Esq., F.R.S., Sec. G.S.
 Hamilton, Sir Wm. R., LL.D., Astronomer
 Royal of Ireland, M.R.I.A., F.R.A.S.
 (deceased).
 Hancock, W. Neilson, LL.D.
 Harcourt, Rev. Wm. Vernon, M.A., F.R.S.
 Hardwicke, Charles Philip, Earl of, F.R.S.
 Harford, J. S., D.C.L., F.R.S.
 Harris, Sir W. Snow, F.R.S.
 Harrowby, The Earl of, F.R.S.
 Hatfeild, William, Esq., F.G.S. (deceased).
 Henry, W. C., M.D., F.R.S.
 Henry, Rev. P. S., D.D., President of Queen's
 College, Belfast.
 Henslow, Rev. Professor, M.A., F.L.S. (dec^d).
 Herbert, Hon. and Very Rev. Wm., LL.D.,
 F.L.S., Dean of Manchester (dec^d).
 Hereford, The Very Rev. the Dean of.
 Herschel, Sir John F.W., Bart., M.A., D.C.L.,
 F.R.S.
 Heywood, Sir Benjamin, Bart., F.R.S.
 (deceased).
 Heywood, James, Esq., F.R.S.
 Hill, Rev. Edward, M.A., F.G.S.
 Hincks, Rev. Edward, D.D., M.R.I.A.
 Hincks, Rev. Thomas, B.A.
 Hinds, S., D.D., late Lord Bishop of Norwich
 (deceased).
 Hodgkin, Thomas, M.D.
 Hodgkinson, Professor Eaton, F.R.S. (dec^d).
 Hodgson, Joseph, Esq., F.R.S.
 Hogg, John, Esq., M.A., F.L.S.
 Hooker, Sir William J., LL.D., F.R.S.
 (deceased).
 Hope, Rev. F. W., M.A., F.R.S. (deceased.)
 Hopkins, William, Esq., M.A., LL.D., F.R.S.
 Horner, Leonard, Esq., F.R.S. (deceased).
 Houghton, Lord, D.C.L.
 Hovenden, V. F., Esq., M.A.
 Hugall, J. W., Esq.
 Hunt, Aug. H., Esq., B.A., Ph.D.
 Hutton, Robert, Esq., F.G.S.
 Hutton, William, Esq., F.G.S. (deceased).
 Ibbetson, Capt. L.L. Boscawen, K.R.E., F.G.S.
 Inglis, Sir R. H., Bart., D.C.L., M.P.
 (deceased).
 Inman, Thomas, M.D.
 Jacobs, Bethel, Esq.
 Jameson, Professor R., F.R.S. (deceased).
 Jardine, Sir William, Bart., F.R.S.E.
 Jeffreys, John Gwyn, Esq., F.R.S.
 Jellett, Rev. Professor.
 Jenyns, Rev. Leonard, F.L.S.
 Jerrard, H. B., Esq.
 Jeune, The Right Rev. F., D.C.L.
 Johnston, Right Hon. William, late Lord
 Provost of Edinburgh.
 Johnston, Prof. J. F. W., M.A., F.R.S. (dec^d).
 Keleher, William, Esq. (deceased).
 Kelland, Rev. Prof. P., M.A., F.R.S. L. & E.
 Kildare, The Marquis of.
 Lankester, Edwin, M.D., F.R.S.
 Lansdowne, Hen., Marquis of, D.C.L., F.R.S.
 (deceased).
 Larcom, Major, R.E., LL.D., F.R.S.
 Lardner, Rev. Dr. (deceased).
 Lassell, William, Esq., F.R.S. L. & E.
 Latham, R. G., M.D., F.R.S.
 Lee, Very Rev. John, D.D., F.R.S.E., Prin-
 cipal of the University of Edinburgh
 (deceased).
 Lee, Robert, M.D., F.R.S.
 Leigh, The Right Hon. Lord.
 Lefevre, Right Hon. Charles Shaw, late
 Speaker of the House of Commons.
 Lemon, Sir Charles, Bart., F.R.S.
 Lichfield, The Right Hon. the Earl of.
 Liddell, Andrew, Esq. (deceased).
 Liddell, Very Rev. H. G., D.D., Dean of
 Christ Church, Oxford.
 Lindley, Professor John, Ph.D., F.R.S.
 (deceased).
 Listowel, The Earl of.
 Liveing, Prof. G. D., M.A., F.C.S.
 Lloyd, Rev. B., D.D., Provost of Trin. Coll.,
 Dublin (deceased).
 Lloyd, Rev. H., D.D., D.C.L., F.R.S. L. & E.,
 M.R.I.A.
 Londesborough, Lord, F.R.S. (deceased).
 Lubbock, Sir John W., Bart., M.A., F.R.S.
 (deceased).

- Luby, Rev. Thomas.
 Lyell, Sir Charles, Bart., M.A., LL.D., D.C.L., F.R.S.
 Lyttelton, The Right Hon. Lord.
 MacCullagh, Prof., D.C.L., M.R.I.A. (dec^d).
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 Macfarlane, The Very Rev. Principal. (dec^d).
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Report of the Council of the British Association, presented to the General Committee, Wednesday, September 6, 1865.

1. The Council has received a Report from the Treasurer, W. Spottiswoode, Esq., at each of its meetings, and his General Report for the year ending September 6, 1865, will be presented to the Committee this day.

2. The Report of the Parliamentary Committee has been received for presentation to the General Committee this day.

3. The Kew Committee has presented a Report to the Council at each of its meetings, and the Report for the year 1864-65 will be laid before the General Committee this day.

4. In addition to the Noblemen and Gentlemen elected at Bath, the Council propose the names of the Right Hon. the Earl of Dudley; the Right Hon. the Lord Lyttelton, Lord-Lieutenant of Worcestershire; A. Follett Osler, Esq., F.R.S.; and the Rev. Charles Evans, M.A., Head Master of King Edward's School, as Vice-Presidents of the present Meeting; and the Rev. G. D. Boyle, M.A., as Local Secretary.

5. The Council have added to the list of Corresponding Members the names of the following Foreign Men of Science, who have been present at Meetings of the Association:—M. E. Hébert, Dr. Arnold Moritz, Herr Neumayer, M. Vámbéry, Dr. Welwitsch.

6. The Council learn with deep regret that the prolonged illness of Mr. Hopkins renders him unable to continue his valuable services in the office of General Secretary.

7. The Council have been informed that invitations will be presented to the General Committee at its meeting on Monday, September 11, from Nottingham, for the year 1866; from Dundee, for the year 1867; and from Norwich and Southampton for an early meeting.

Report of the Kew Committee of the British Association for the Advancement of Science for 1864-65.

The Committee of the Kew Observatory submit to the Council of the British Association the following statement of their proceedings during the past year:—

A short time before the Meeting at Bath, it had been decided by the Secretary of State for India, on the recommendation of the President and Council of the Royal Society, that pendulum observations should be made in India, and that the officer appointed to conduct this experimental investigation might receive instruction at Kew Observatory, which might form the base-station of the Indian series.

In consequence of this decision Captain Basevi, R.E., first assistant in the Indian Trigonometrical Survey, received instruction at Kew Observatory in the method of making and reducing pendulum observations, and in that of taking transits. Colonel Walker, R.E., Superintendent of the Survey, also attended, in order to make himself acquainted with the details of the apparatus and the method of observing.

The pendulums used were those marked No. 1821 and No. 4, used formerly by General Sabine in different parts of the globe. The former was also used by Mr. Airy in his Harton Colliery experiments.

A receiver, by means of which these pendulums might be vibrated *in vacuo*, was constructed by Mr. Adie, optician, London. A convenient room for pendulum observations was likewise fitted up in the Observatory, the expense being defrayed from the Government Grant Fund of the Royal Society; 1865.

and in this room the preliminary observations were made for determining the constants of the two pendulums about to be used in India. These observations were made by Mr. Loewy, and the results have been communicated to the Royal Society by the Superintendent, in conjunction with the observer. The pendulums and other apparatus were subsequently taken to India by Mr. J. Hennessey, and have arrived safely at the head quarters of the Trigonometrical Survey.

General Sabine has been informed by Mr. Meldrum, Director of the Mauritius Observatory, that the necessary funds have been voted by the Government of that colony for hourly meteorological and magnetical observations; and that he may shortly be expected in this country, in order to become acquainted with the working of the Kew instruments. In consequence of this communication, Mr. Adie has constructed a set of self-recording magnetographs, in readiness for Mr. Meldrum's arrival.

A Dip Circle and Unifilar have been verified at Kew, and will shortly be dispatched to Mr. Ellery, Director of the Observatory, Melbourne, Australia.

Two Dip Circles and two Unifilars, ordered by Colonel Walker, R.E., Superintendent of the Indian Survey, have been verified in the presence of Colonel Walker, who has received instruction in the method of observation with these instruments. They have since been sent to India, where they have safely arrived.

Three Dip Circles and three Unifilars, ordered by Colonel Strange, are being verified at the Observatory, and likewise one Dip Circle and one Unifilar recently ordered by Captain J. Belavenetz of the Russian Navy, for the Compass Observatory just built at Cronstadt.

Mr. E. Walker (who has received the Cambridge Adams prize for his essay on terrestrial magnetism) has been at Kew Observatory, receiving instruction in the use of magnetical instruments.

The usual monthly absolute determinations of the magnetic elements continue to be made; and the self-recording magnetographs are in constant operation, as heretofore, under Mr. Whipple, magnetical assistant, who has displayed much care and assiduity in the discharge of his duties.

The meteorological work of the Observatory continues to be performed by Mr. Thomas Baker, who likewise takes charge of the photographic department connected with the self-recording instruments, and executes both offices very satisfactorily.

Since the Meeting at Bath, Senhor da Souza, of the University of Coimbra, has ordered a self-recording barograph and thermograph, an anemometer and electrograph, tubes for filling by Mr. Welsh's process in order to obtain a standard barometer, and a cathetometer. These instruments have been constructed by opticians, and forwarded to Coimbra.

During the past year, 88 barometers and 420 thermometers have been verified, and 6 standard thermometers have been supplied to men of science and opticians; 3 sets of measures of capacity have likewise been verified.

The Self-recording Barograph continues in constant operation, and traces in duplicate are obtained, one set of which has been regularly forwarded to the meteorological department of the Board of Trade.

At the request of Mr. Charles Cator, an anemometer of his construction has been tested at the Observatory, and the results communicated to him. Also, at the request of Professor Roscoe, the photographic action of total daylight is daily registered by an apparatus of his construction.

The Kew Heliograph, in charge of Mr. De la Rue, continues to be worked by a qualified assistant, who gives much satisfaction. During the past year 243 negatives have been taken, on 146 days, and four sets of positives

have been printed from each, some of which have been given to men of science interested in this branch of research.

The negatives are being reduced under the superintendence of Mr. De la Rue, and by means of an instrument of his own construction, which he has generously presented to the Kew Committee. Mr. B. Loewy has been engaged in the reduction, which he is executing satisfactorily.

It was mentioned in last Report that an addition to the Micrometer was in the course of construction, by means of which the proportion of the sun's disk obscured by spots might be conveniently measured. This arrangement is now completed; and the materials for measurement have been greatly increased through the kindness of Mr. Carrington, who has placed his original drawings, in which the size and appearance of the spots are delineated with great fidelity, at the disposal of the Kew Observatory. It may be desirable to state in a few words the proposed method of exhibiting the results of these reductions. In the progress of this branch of knowledge observers have been led to recognize certain laws which represent the average behaviour of sun-spots; but to all of these laws there are individual exceptions. In this state of things it is probable that our knowledge of the subject will ultimately be advanced, not only by a study of those groups which behave in a normal manner, but also by a study of those which are exceptions in their behaviour to the general rule; and on this account it has been thought desirable to publish the results in such a way that anyone may be able to study the appearance and behaviour—in fact the whole history—of any one group.

In order to accomplish this, a lens is being made by Dallmeyer, by means of which individual groups may be magnified to a scale on which the diameter of the sun will be equal in size to two feet.

The sun-spots continue to be observed after the method of Hofrath Schwabe, of Dessau.

As Kew is the first public institution which has taken up the subject of sun-spots, and as it is intended to continue the method of numbering groups so long and successfully adopted by Hofrath Schwabe, it was thought desirable to endeavour to procure, if possible, for this country the original drawings made by this eminent and assiduous observer during a course of about forty years. A joint letter by Mr. De la Rue and Mr. Stewart was consequently addressed to Hofrath Schwabe; and the following answer to it was soon received.

“GENTLEMEN,—The request contained in your letter, although in the highest degree honourable and complimentary to me, and although it gives me an opportunity to show the Royal Astronomical Society my gratitude for the Royal Medal granted to me, has still cost me some struggle before complying with it; for it is not easy to part with what has given me very often much pleasure and enjoyment as a compensation for the labour devoted to the work.

“But in complying with your desire I do so on one condition, viz. that you would grant me permission to obtain the observations back again at any time that I should be desirous of looking into them, during the short time of life still left to me. I do not think that I shall have an occasion to avail myself of the permission asked for; but permit me kindly to believe that it is in my power to do so. After my death you may consider the whole of the observations as the property of the Royal Astronomical Society.

“Please to write me if you are willing to agree to the above desire, and I shall then immediately send you my astronomical diaries, &c. from 1825 to the end of 1864.

“I remain, Gentlemen,

“Yours very faithfully,

“S. H. SCHWABE.”

In order to realize this generous bequest of Hofrath Schwabe, Mr. Loewy of the Kew Observatory went to Dessau, taking with him a selection of duplicate negatives and prints of the sun, which he presented, in the name of the Association, to that gentleman. After receiving Mr. Loewy most courteously, Hofrath Schwabe expressed his gratification at the high degree of perfection attained in photoheliography, which surpassed his most sanguine expectations; he also handed over to Mr. Loewy's trust not only his valuable collection of sun-drawings, but also all his astronomical observations. Some of these will be exhibited at the Association.

It has long been a desideratum in photoheliography, with the view of obtaining the apparent diameter of the sun's disk, to ascertain the *absolute* values in arc of the divisions of the measuring-instrument (Mr. De la Rue's Micrometer), and preliminary experiments were made with that object during the period that the Heliograph was at the Cranford Observatory. These were only partially successful. The mode of operation was this: a suitable object sufficiently distant was photographed by means of the Kew instrument, with the lenses in the same positions as when solar pictures were taken. Different portions of the object (windows, doors, &c. of a house, for example) were then carefully measured so as to ascertain their value in minutes and seconds of arc; and by measuring the pictures of these several portions with the arbitrary scale of the Micrometer, the value of the latter in arc could be calculated. The experiments did not succeed so well as could have been desired, in consequence of the disturbance of the images by the undulations of the atmosphere, none but very low objects coming within the desired range. More recently, however, the experiments have been taken up again with great promise, and excellent photographs of the Kew Pagoda have been obtained, which possess the requisite sharpness. The object itself, on account of its numerous galleries, is peculiarly fitted for such observations, as it will be possible to ascertain and allow for any optical distortion of the photographic image. Thus it is not improbable that the Pagoda will afford the means of ascertaining, photographically, with the greatest accuracy, the angular diameter of the sun, and will give data for correcting the assumed semidiameter of the moon, by the discussion of photographic pictures of solar eclipses.

M. Gussew has informed Mr. De la Rue that the Wilna Heliograph is now at work under his direction, during the absence, on account of ill health, of the Director, Prof. Sabler. At present he experiences some difficulty in obtaining perfect photographs, and he has been invited to receive instruction at the Kew Observatory. It is considered to be desirable on other accounts that M. Gussew should be able to avail himself of the advantage thus offered to him, as an arrangement might then be made for the division of the labour of reducing the Heliographic observations.

An apparatus will shortly be added to the Kew Observatory for the important object of the ready verification of sextants; the system of distant mirrors now in use, designed by Mr. Galton and erected at his own cost, being only available in steady sunshine.

The new apparatus has been designed by Mr. Thomas Cooke, the well-known optician. In principle, it consists of four collimators fixed radially, at various angles apart, round the table on which the sextant is to be laid for examination. The cross wires of the collimators in each of their combinations are to be brought successively into contact by the sextant. Then a comparison of its readings with the constant angles of construction of the apparatus determines the error of the sextant at various points of its arc. However, in practice, to avoid the cost of very large collimators, whose

object-glasses would suffice to include the rays proceeding both to the index and to the horizon-glasses of large sextants, Mr. Cooke employs *double* collimators of moderate size; and he adjusts each pair to strict parallelism by aid of a detached telescope.

The coloured shades of the sextant are readily examined by strongly illuminating the fields of two of the collimators, after contact of their cross wires has been made in the ordinary manner.

On the application of Mr. Galton, backed by the recommendation of the Kew Committee, the Council of the Royal Society has allotted £80 from the Government Grant, to defray the estimated cost of Mr. Cooke's apparatus, and its establishment in the Observatory at Kew.

The apparatus will be erected in the basement-hall of the Observatory; and when the arrangement is complete it is hoped that the Observatory will become a place where quadrants and sextants can be verified with great facility, and where scientific travellers or officers in Her Majesty's Service may receive instruction in the use of geographical instruments.

The solar spectrum is being mapped by the spectroscope belonging to the Chairman. All the measurements for the region between D and E have been made and carefully verified; and a map of this region, in accordance with these measurements, has been constructed by Mr. Loewy. Many more lines are exhibited in this map than in that lately made by Professor Kirchhoff. Observations made by this instrument have likewise brought out several new lines in the spectrum of ignited sodium.

At the joint suggestion of Professor Tait of Edinburgh and the Superintendent, an ingenious apparatus has been constructed by Mr. Beckley, by means of which a disk can be made to revolve *in vacuo* with great velocity; and a short description of some experiments performed by means of this instrument, with the view of ascertaining whether visible as well as molecular motion is dissipated by a medium pervading space, has been communicated to the Royal Society by the Superintendent in conjunction with Professor Tait.

The instrument devised by Mr. Broun, for the purpose of estimating the magnetic dip by means of soft iron, remains at present at the Observatory.

The Superintendent has received grants from the Royal Society for special experiments; and when these are completed, an account will be rendered to that Society.

It will be seen from the foregoing Report, that many other experiments and observations, of a nature to advance science, are made under the sanction of the Committee, besides those which form the ordinary work of the Observatory; it is, however, always stipulated that the cost of such experiments shall be defrayed by their promoters.

J. P. GASSIOT,
Chairman.

Kew Observatory,
31st August, 1865.

Accounts of the Kew Committee of the British Association from September 14, 1864 to September 6, 1865.

RECEIPTS.

	£	s.	d.
Received from the General Treasurer	600	0	0
" for the verification of Meteorological Instruments, from the Board of Trade ..	4	5	0
" from the Admiralty	10	15	0
" from Opticians	35	15	6
" for Barograph Curves sent to the Meteorologic Office, London	26	1	5
" for the verification of portable Magnetometers	20	0	0
" for the construction of standard Thermometers	3	5	0
Received by the Superintendent for time of the Observatory Staff occupied in preparing pendulum-room, making and reducing pendulum observations, &c.....	50	0	0
	150	1	11

£750 1 11

I have examined the above account and compared it with the vouchers presented to me.
The Receipts amount to.....
And for expenses connected with Pendulum Observations.....

Last Year's Balance.....

The total Expenditure for the year.....

Leaving a balance in hand amounting to.....

29th August, 1865.

R. HUTTON.

PAYMENTS.

	£	s.	d.
Balance from last account	45	17	9
Salaries, &c.:—			
To B. Stewart, four quarters, ending 1st October, 1865.....	200	0	0
Ditto, allowed for petty travelling expenses.....	10	0	0
G. Whipple, four quarters, ending 18th September, 1865.....	85	0	0
T. Baker, four quarters, ending 29th September, 1865	60	0	0
R. Beckley, 51 weeks, ending 4th September, 1865, at 40s. per week	102	0	0
Ditto, gratuity allowed for travelling expenses.	15	0	0
F. Page, 3 weeks, ending 3rd October, 1864, at 10s. per week.....	1	10	0
Ditto, 48 weeks, ending 4th September, 1865, at 12s. per week	28	16	0
Apparatus, Materials, Tools, &c.	502	6	0
Ironmonger, Carpenter, and Mason	32	3	9
Printing, Stationery, Books, and Postage	1	4	0
Coals and Gas	29	17	8
House Expenses, Chandlery, &c.	47	11	1
Porterage and petty expenses	29	4	8
Rent of Land to 10th October, 1865, and half payment for horse which fell into ditch	16	12	4
Balance.....	18	10	0
	26	14	8
	£750	1	11

£700 1 11

50 0 0

750 1 11

£ 45 17 9

723 7 3

£ 26 14 8

Report of the Parliamentary Committee to the Meeting of the British Association at Birmingham, September 1865.

The Parliamentary Committee have the honour to report as follows:—

By a Resolution passed at Bath your Committee were requested to press on the Government the expediency of instituting a series of experiments on Fog Signals, but on consulting some of the Members of the Committee appointed for the purpose of making experiments on the transmission of sound under water, your Committee were informed that no action on the part of the Government was at present necessary.

Your Committee brought under the notice of the Council the unsatisfactory character of the provisions of the Public Schools Bill of last Session, so far as they affected the interests of Science.

Your Committee advocated such alterations therein as they believed would be most likely to promote these interests; and it was at the suggestion of one of their members that Professors Sharpey, W. A. Miller, Huxley, and Tyndall were applied to, and gave the admirable evidence on the extent to which Physical Science might with advantage be introduced into the studies of our great Public Schools, which will be found in the Appendix to the Report of the Committee of the House of Lords on the Bill above referred to, and to which the attention of all engaged in the instruction of youth may be usefully directed. Some valuable remarks on the same subject by our President Elect had been previously referred to in the course of the Debate; and the evidence of our President, Drs. Carpenter and Hooker, the Astronomer Royal, and others, before the Public School Commissioners, furnishes an additional proof, if any were wanting, of the zeal and energy with which the Cultivators of Science continue to remonstrate against the system, which still unhappily prevails in many of our Schools, of ignoring the claims of Science.

WROTTESLEY, *Chairman.*

31st August, 1865.

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE BIRMINGHAM
MEETING IN SEPTEMBER 1865.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That the sum of £600 be placed at the disposal of the Council for maintaining the Establishment of the Kew Observatory.

That the Lunar Committee, consisting of Mr. J. Glaisher, Lord Rosse, The Rev. T. W. Webb, Mr. W. R. Birt, Dr. Lee, Mr. J. N. Lockyer, Rev. W. R. Dawes, Sir J. Herschel, Bart., Professor Phillips, Mr. J. Nasmyth, Mr. Warren De la Rue, and Mr. H. S. Ellis, be reappointed, with the object of making further progress in mapping the surface of the Moon; that Mr. W. R. Birt be Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on Electrical Standards, consisting of Professor Williamson, Professor Wheatstone, Professor W. Thomson, Professor W. A. Miller, Dr. A. Matthiessen, Mr. Fleeming Jenkin, Sir Charles Bright, Professor Maxwell, Mr. C. W. Siemens, Mr. Balfour Stewart, Dr. Joule, and Mr. C. F. Varley, be reappointed, with power to add to their number; that Mr. Fleeming Jenkin be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on Luminous Meteors and Aërolites, consisting of Mr. Glaisher, Mr. R. P. Greg, Mr. E. W. Brayley, and Mr. Alexander Herschel, be reappointed; that Mr. Herschel be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That the Balloon Committee, consisting of Colonel Sykes, Mr. Airy, Lord Wrottesley, Sir David Brewster, Sir J. Herschel, Bart., Dr. Lee, Dr. Robinson, Mr. Fairbairn, Dr. Tyndall, Dr. W. A. Miller, and Mr. Glaisher, be reappointed for the purpose of making night observations at any time of the year, and day observations in the months of October to April; and electrical observations if possible; that Mr. Glaisher be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Dr. Robinson, Professor Wheatstone, Dr. Gladstone, and Professor Hennessy be reappointed (with power to add to their number) for the purpose of making experiments on the Transmission of Sound under Water; and that the sum of £30 be placed at their disposal for the purpose.

That Mr. Glaisher, Lord Wrottesley, Professor Phillips, Professor Tyndall, Dr. Lee, Mr. G. J. Symons, Mr. F. J. Bateman, and Mr. R. W. Mylne be a Committee for the purpose of continuing the Reports on the Rainfall of the British Isles; and that the sum of £50 be placed at their disposal for that purpose.

That the Astronomer Royal, Lord Wrottesley, Sir J. Herschel, Bart., Dr. Lee, Mr. W. De la Rue, and Mr. Glaisher (with power to add to their number) be a Committee for the purpose of examining the late Dr. Rümker's Astronomical Observations in the Southern Hemisphere; and in case they should be of opinion that it is desirable these observations should be reduced for publication, a sum of £150 be granted to Professor G. Rümker, M.A., for that purpose.

That Mr. Thomas Fairley be requested to continue his researches on the

Polycyanides of Organic Radicals; and that £20 be placed at his disposal for that purpose.

That Dr. Matthiessen be requested to investigate the chemical constitution of Cast Iron; and that the sum of £50 be placed at his disposal for the purpose.

That the Committee appointed at Bath (Sir Charles Lyell, Bart., Professor Phillips, Sir J. Lubbock, Bart., Mr. J. Evans, Mr. E. Vivian, and Mr. W. Pengelly) to investigate Kent's Hole, Torquay, be requested to continue the exploration; that Mr. W. Pengelly be the Secretary, and that the further sum of £200 be placed at their disposal for the purpose.

That Messrs. W. S. Mitchell, J. Prestwich, and H. Woodward be a Committee for the purpose of investigating the Fossil-Leaf Bed in Alum Bay, Isle of Wight; that the specimens be placed in the British Museum; and that the sum of £20 be placed at their disposal for the purpose.

That Dr. E. Perceval Wright and Professor Harkness be a Committee for the purpose of assisting Mr. Brownrig in exploring the Kilkenny Coal Field; that the Fossils thus obtained be placed in some National museum; and that the sum of £20 be placed at their disposal for the purpose.

That Professor Busk and Captain Spratt be a Committee for the purpose of continuing to assist Dr. Leith Adams in the exploration of the Maltese Caverns; and that the further sum of £30 be placed at their disposal for the purpose.

That Sir Roderick I. Murchison, Professor Owen, the Earl of Ducie, Sir Henry Rawlinson, and the Rev. H. B. Tristram be a Committee for the purpose of aiding the Palestine Exploration Fund in exploring the Geology, Geography, and Zoology of the Holy Land; and that the sum of £100 be placed at their disposal for the purpose.

That the Committee appointed at Bath, consisting of Mr. J. W. Salter, Mr. R. Lightbody, Mr. Vicary, and Mr. J. E. Lee, be reappointed for the purpose of assisting Mr. Hicks in further excavations in the Lingula Flags at St. David's; and that an illustrative suite of the Fossils be placed in the Museum of Practical Geology, Jermyn Street; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. J. Bryce, Mr. Milne Home, and Mr. M^cFarlan be a Committee for the purpose of studying Earthquake Shocks in Scotland; and that the sum of £25 be placed at their disposal for the purpose.

That Dr. E. Perceval Wright and Dr. Carte be a Committee for the purpose of reporting on the Irish Annelids; and that the sum of £15 be placed at their disposal for the purpose.

That Mr. A. Newton, Rev. H. B. Tristram, and Dr. Selater be a Committee for the purpose of assisting Mr. E. Newton in his researches for the remains of the extinct Didine birds of the Mascareen Islands, and to report thereon at the next Meeting of the Association; and that the sum of £50 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Mr. Robert M^cAndrew, Mr. Edward Waller, Rev. A. M. Norman, and Mr. H. K. Jordan be a Committee for the purpose of exploring the Coasts of the Hebrides by means of the dredge; and that the sum of £50 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Mr. C. Spence Bate, Mr. John Couch, Mr. B. Rowe, Mr. C. Stewart, and the Rev. Dr. Hincks be a Committee for investigating the Marine Flora and Fauna of the southern coasts of Devon and Cornwall; and that the sum of £25 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Rev. W. Gregor, and Mr. Robert Dawson be a Committee for the purpose of exploring the Coasts of Aberdeenshire and Banffshire; and that the sum of £25 be placed at their disposal for the purpose.

That Dr. Scott, Mr. C. Stewart, and Mr. H. S. Ellis be a Committee for the purpose of making experiments on Oyster Culture in the West of England; and that the sum of £10 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Dr. Collingwood, Rev. H. H. Higgins, Mr. Isaac Byerley, Dr. J. B. Edwards, and Mr. Thomas J. Moore be a Committee for the purpose of dredging the Estuary of the Mersey; and that the sum of £5 be placed at their disposal for the purpose.

That Dr. J. E. Gray, Mr. C. Spence Bate, and Mr. Frank Buckland be a Committee for the purpose of reporting on Oyster Culture; and that the sum of £25 be placed at their disposal for the purpose.

That Sir John Lubbock Bart., Sir Henry Rawlinson, Mr. John Crawford, Professor Huxley, and Mr. Francis Galton be a Committee for the purpose of aiding the researches of Mr. George Busk on Typical Crania; and that the sum of £50 be placed at their disposal for the purpose.

That Dr. Barnard Davis, Professor Acland, and Professor Rolleston be a Committee for the purpose of preparing a Catalogue of Crania; and that the sum of £50 be placed at their disposal for that purpose.

That a grant of £10 be made to Dr. Richard Norris to enable him to pursue physiological experiments on Rigor Mortis.

That a grant of £25 be made to Dr. B. W. Richardson to enable him to pursue his physiological experiments on the Amyl Series and allied organic compounds.

That Sir John Bowring, Lord Wrottesley, The Right Hon. C. B. Adderley, Sir William Armstrong, The Astronomer Royal, Samuel Brown, W. Ewart, T. Graham, Sir John Hay, Bart., Professor Hennessy, James Heywood, Dr. Lee, Dr. Leone Levi, Professor W. A. Miller, Professor Rankine, Rev. Dr. Robinson, Colonel Sykes, W. Tite, Professor A. W. Williamson, James Yates, Sir Robert Kane, F. P. Fellows, C. W. Siemens, Matthew Arnold, Right Hon. Earl Fortescue, Dr. Dieterici, Follett Osler, Ralph Heaton, I. de Meschen, and P. Le Neve Foster (with power to add to their number), be a Committee, with power to use such measures as they may deem expedient for promoting the extensive use of the Metric System in scientific documents, as well as the teaching of the system in schools and colleges, and for the general information of the people; that Professor Leone Levi be the Secretary, and that the sum of £50 be placed at their disposal for the furtherance of these objects.

That the Patent Law Committee be reappointed, and that it consist of the following Members:—Mr. Thomas Webster, Sir W. G. Armstrong, Mr. J. F. Bateman, Mr. W. Fairbairn, Mr. John Hawkshaw, Mr. J. Scott Russell, Mr. John Bethel, and Mr. Peter Le Neve Foster; and that the grant of £30, previously made and not drawn, be renewed.

That the Committee for the purpose of experimenting on the difference between the resistance of water to floating and to immersed bodies, consisting of J. Scott Russell, Mr. J. R. Napier, Professor Rankine, and Mr. W. Froude, be reappointed; and that the sum of £50 be placed at their disposal for the purpose.

Applications for Reports and Researches not involving Grants of Money.

That Professor Stokes be requested to continue his Report on Physical Optics.

That Professor Smith be requested to continue and conclude his Report on the Theory of Numbers.

That Professor Wanklyn be requested to continue his Research on the Hexylic Compounds.

That the Committee on Scientific Evidence in Courts of Law, consisting of the Rev. W. V. Harcourt, Professor Williamson, The Right Hon. J. Napier, Mr. W. Tite, Professor Christison, Mr. James Heywood, Mr. J. F. Bateman, Mr. Thomas Webster, Sir Benjamin Brodie, Bart., and Professor W. A. Miller (with power to add to their number) be reappointed; and that Professor Williamson be the Secretary.

That Dr. Paul be requested to continue his Report on the Application of Chemistry to Geology.

That Dr. Baker Edwards be requested to continue his Research on the Alkaloidal Principles of the Calabar Bean.

That Mr. J. F. Spencer, not having been able to complete his Report "On the different modes of estimating the nominal horse-power of Marine Engines, with a view of securing a uniform system," be requested to continue his labours, and Report at the next Meeting.

That the Gun-Cotton Committee, consisting of Mr. Fairbairn, Mr. Joseph Whitworth, Mr. James Nasmyth, Mr. J. Scott Russell, Mr. John Anderson, Sir William G. Armstrong, Dr. Gladstone, Professor W. A. Miller, Dr. Frankland, and Mr. Abel, be reappointed and requested to continue their Report.

Involving Application to Government.

That Sir Roderick Murchison, Admiral R. Collinson, Admiral Ommanney, and Mr. C. R. Markham be a Committee for the purpose of representing to Her Majesty's Government the advantage to several branches of Science that would be derived from the exploration of the unknown region around the North Pole.

Communications to be printed in extenso.

That the Addresses of the Presidents of the Sections be printed *in extenso* in the Transactions.

That the Paper read by Mr. Follett Osler on September 11, "On the Horary and Diurnal Variations in the Motion of the Air," with Diagrams illustrating the same, be printed *in extenso* in the Reports of the Association.

That Mr. Bessemer's Paper "On the Manufacture of Cast Steel, its progress and employment as a substitute for Wrought Iron," be printed *in extenso* in the Transactions of the Sections.

That the title of Section D be changed to Biology, and that the Council be charged with making the requisite arrangements.

The Committee unanimously recommend that for the word "Subsection" in the third paragraph of the business of Sections the word "Department" be substituted.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Birmingham Meeting in September 1865. The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.

	£	s.	d.
<i>Kew Observatory.</i>			
Maintaining the Establishment of Kew Observatory	600	0	0

Mathematics and Physics.

Glaisher, Mr.—Lunar Committee	100	0	0
Williamson, Prof.—Electrical Standards	100	0	0
Glaisher, Mr.—Luminous Meteors and Aërolites	50	0	0
Sykes, Col.—Balloon Experiments	100	0	0
Robinson, Dr.—Sound under Water (renewed)	30	0	0
Glaisher, Mr.—British Rainfall	50	0	0
Airy, Mr.—Reduction of Rümker Observations	150	0	0

Chemistry.

Fairley, Mr.—Polycyanides of Organic Radicals	20	0	0
Matthiessen, Dr.—Chemical Constitution of Cast Iron (renewed)	50	0	0

Geology.

Lyell, Sir C.—Kent's Hole Investigation	200	0	0
Mitchell, Mr.—Alum Bay Fossil Leaf Bed	20	0	0
Wright, Dr. E. P.—Kilkenny Coal-field	20	0	0
Busk, Professor.—Maltese Caverns Explorations	30	0	0
Murchison, Sir R.—Palestine Explorations	100	0	0
Salter, Mr. J. W.—Lingula Flags at St. David's	20	0	0
Bryce, Mr. J.—Researches on Earthquakes in Scotland	25	0	0

Zoology, Botany, and Physiology.

Wright, Dr. E. P.—Irish Annelida	15	0	0
Newton, Mr.—Didine Birds of Mascareen Islands	50	0	0
Jeffreys, Mr.—Hebrides Coast Dredging	50	0	0
Jeffreys, Mr.—Marine Fauna and Flora (Devon and Cornwall)	25	0	0
Jeffreys, Mr.—Aberdeen and Banffshire Coast Dredging	25	0	0
Scott, Mr.—Oyster Culture in the West of England	10	0	0
Jeffreys, Mr.—Mersey Dredging	5	0	0
Gray, Dr. J. E.—Oyster Culture	25	0	0
Davis, Dr. Barnard.—Catalogue of Crania	50	0	0
Norris, Dr. Richard.—Observations on Rigor Mortis	10	0	0
Richardson, Dr. B. W.—Amyl Compounds	25	0	0

Geography and Ethnology.

Lubbock, Sir J.—Typical Crania (renewed)	50	0	0
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Statistics and Economic Science.

Bowring, Sir J.—Metrical Committee	50	0	0
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Mechanics.

Webster, Mr.—Patent Laws (renewed)	30	0	0
Russell, J. Scott, Mr.—Resistance of Water to Floating Bodies	50	0	0

Total 2135 0 0

*General Statement of Sums which have been paid on Account of Grants
for Scientific Purposes.*

	£	s.	d.		£	s.	d.
1834.				Meteorology and Subterranean			
Tide Discussions	20	0	0	Temperature	21	11	0
1835.				Vitrification Experiments	9	4	7
Tide Discussions	62	0	0	Cast Iron Experiments	100	0	0
British Fossil Ichthyology	105	0	0	Railway Constants	28	7	2
	<u>£167</u>	<u>0</u>	<u>0</u>	Land and Sea Level	274	1	4
1836.				Steam-vessels' Engines	100	0	0
Tide Discussions	163	0	0	Stars in Histoire Céleste	331	18	6
British Fossil Ichthyology	105	0	0	Stars in Lacaille	11	0	0
Thermometric Observations, &c.	50	0	0	Stars in R.A.S. Catalogue	6	16	6
Experiments on long-continued				Animal Secretions	10	10	0
Heat	17	1	0	Steam-engines in Cornwall	50	0	0
Rain-Gauges	9	13	0	Atmospheric Air	16	1	0
Refraction Experiments	15	0	0	Cast and Wrought Iron	40	0	0
Lunar Nutation	60	0	0	Heat on Organic Bodies	3	0	0
Thermometers	15	6	0	Gases on Solar Spectrum	22	0	0
	<u>£434</u>	<u>14</u>	<u>0</u>	Hourly Meteorological Observa-			
1837.				tions, Inverness and Kingussie	49	7	8
Tide Discussions	284	1	0	Fossil Reptiles	118	2	9
Chemical Constants	24	13	6	Mining Statistics	50	0	0
Lunar Nutation	70	0	0		<u>£1595</u>	<u>11</u>	<u>0</u>
Observations on Waves	100	12	0	1840.			
Tides at Bristol	150	0	0	Bristol Tides	100	0	0
Meteorology and Subterranean				Subterranean Temperature	13	13	6
Temperature	89	5	0	Heart Experiments	18	19	0
Vitrification Experiments	150	0	0	Lungs Experiments	8	13	0
Heart Experiments	8	4	6	Tide Discussions	50	0	0
Barometric Observations	30	0	0	Land and Sea Level	6	11	1
Barometers	11	18	6	Stars (Histoire Céleste)	242	10	0
	<u>£918</u>	<u>14</u>	<u>6</u>	Stars (Lacaille)	4	15	0
1838.				Stars (Catalogue)	264	0	0
Tide Discussions	29	0	0	Atmospheric Air	15	15	0
British Fossil Fishes	100	0	0	Water on Iron	10	0	0
Meteorological Observations and				Heat on Organic Bodies	7	0	0
Anemometer (construction) ..	100	0	0	Meteorological Observations ..	52	17	6
Cast Iron (Strength of)	60	0	0	Foreign Scientific Memoirs	112	1	6
Animal and Vegetable Substances				Working Population	100	0	0
(Preservation of)	19	1	10	School Statistics	50	0	0
Railway Constants	41	12	10	Forms of Vessels	184	7	0
Bristol Tides	50	0	0	Chemical and Electrical Pheno-			
Growth of Plants	75	0	0	mena	40	0	0
Mud in Rivers	3	6	6	Meteorological Observations at			
Education Committee	50	0	0	Plymouth	80	0	0
Heart Experiments	5	3	0	Magnetical Observations	185	13	9
Land and Sea Level	267	8	7		<u>£1546</u>	<u>16</u>	<u>4</u>
Subterranean Temperature	8	6	0	1841.			
Steam-vessels	100	0	0	Observations on Waves	30	0	0
Meteorological Committee	31	9	5	Meteorology and Subterranean			
Thermometers	16	4	0	Temperature	8	8	0
	<u>£956</u>	<u>12</u>	<u>2</u>	Actinometers	10	0	0
1839.				Earthquake Shocks	17	7	0
Fossil Ichthyology	110	0	0	Acrid Poisons	6	0	0
Meteorological Observations at				Veins and Absorbents	3	0	0
Plymouth	63	10	0	Mud in Rivers	5	0	0
Mechanism of Waves	144	2	0	Marine Zoology	15	12	8
Bristol Tides	35	18	6	Skeleton Maps	20	0	0
				Mountain Barometers	6	18	6
				Stars (Histoire Céleste)	185	0	0

	£	s.	d.		£	s.	d.
Stars (Lacaille)	79	5	0	Meteorological Observations, Os-	20	0	0
Stars (Nomenclature of)	17	19	6	ler's Anemometer at Plymouth			
Stars (Catalogue of)	40	0	0	Reduction of Meteorological Ob-	30	0	0
Water on Iron	50	0	0	servations			
Meteorological Observations at				Meteorological Instruments and	39	6	0
Inverness	20	0	0	Gratuities			
Meteorological Observations (re-	25	0	0	Construction of Anemometer at	56	12	2
duction of)				Inverness			
Fossil Reptiles	50	0	0	Magnetic Cooperation	10	8	10
Foreign Memoirs	62	0	0	Meteorological Recorder for Kew			
Railway Sections	38	1	6	Observatory	50	0	0
Forms of Vessels	193	12	0	Action of Gases on Light	18	16	1
Meteorological Observations at				Establishment at Kew Observa-			
Plymouth	55	0	0	tory, Wages, Repairs, Furni-	133	4	7
Magnetical Observations	61	18	8	ture and Sundries			
Fishes of the Old Red Sandstone	100	0	0	Experiments by Captive Balloons	81	8	0
Tides at Leith	50	0	0	Oxidation of the Rails of Railways	20	0	0
Anemometer at Edinburgh	69	1	10	Publication of Report on Fossil			
Tabulating Observations	9	6	3	Reptiles	40	0	0
Races of Men	5	0	0	Coloured Drawings of Railway			
Radiate Animals	2	0	0	Sections	147	18	3
	£1235	10	11	Registration* of Earthquake			
				Shocks	30	0	0
1842.				Report on Zoological Nomencla-	10	0	0
Dynamometric Instruments	113	11	2	ture			
Anoplura Britannicæ	52	12	0	Uncovering Lower Red Sand-	4	4	6
Tides at Bristol	59	8	0	stone near Manchester			
Gases on Light	30	14	7	Vegetative Power of Seeds	5	3	8
Chronometers	26	17	6	Marine Testacea (Habits of) ..	10	0	0
Marine Zoology	1	5	0	Marine Zoology	10	0	0
British Fossil Mammalia	100	0	0	Marine Zoology	2	14	11
Statistics of Education	20	0	0	Preparation of Report on British			
Marine Steam-vessels' Engines ..	28	0	0	Fossil Mammalia	100	0	0
Stars (Histoire Céleste)	59	0	0	Physiological Operations of Me-			
Stars (Brit. Assoc. Cat. of)	110	0	0	dicinal Agents	20	0	0
Railway Sections	161	10	0	Vital Statistics	36	5	8
British Belemnites	50	0	0	Additional Experiments on the			
Fossil Reptiles (publication of				Forms of Vessels	70	0	0
Report)	210	0	0	Additional Experiments on the			
Forms of Vessels	180	0	0	Forms of Vessels	100	0	0
Galvanic Experiments on Rocks	5	8	6	Reduction of Experiments on the			
Meteorological Experiments at				Forms of Vessels	100	0	0
Plymouth	68	0	0	Morin's Instrument and Constant			
Constant Indicator and Dynamo-				Indicator	69	14	10
metric Instruments	90	0	0	Experiments on the Strength of			
Force of Wind	10	0	0	Materials	60	0	0
Light on Growth of Seeds	8	0	0		£1565	10	2
Vital Statistics	50	0	0				
Vegetative Power of Seeds	8	1	11	1844.			
Questions on Human Race	7	9	0	Meteorological Observations at	12	0	0
	£1449	17	8	Kingussie and Inverness			
				Completing Observations at Ply-	35	0	0
1843.				mouth			
Revision of the Nomenclature of				Magnetic and Meteorological Co-	25	8	4
Stars	2	0	0	operation			
Reduction of Stars, British Asso-	25	0	0	Publication of the British Asso-	35	0	0
ciation Catalogue				ciation Catalogue of Stars			
Anomalous Tides, Frith of Forth	120	0	0	Observations on Tides on the	100	0	0
Hourly Meteorological Observa-				East coast of Scotland			
tions at Kingussie and Inverness	77	12	8	Revision of the Nomenclature of			
Meteorological Observations at				Stars	2	9	6
Plymouth	55	0	0	Maintaining the Establishment in			
Whewell's Meteorological Ane-				Kew Observatory	117	17	3
nometer at Plymouth	10	0	0	Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants.....	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata ...	100	0	0
Registering the Shocks of Earth- quakes	1842	23	11 10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas.....	1842	100	0 0
Geographical Distributions of Marine Zoology.....	1842	0	10 0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds	1842	8	7 3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument, 1842	10	3	6
	<u>£981</u>	<u>12</u>	<u>8</u>

1845.

Publication of the British Associa- tion Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co- operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Ob- servations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells...	20	0	0
Exotic Anoplura	1843	10	0 0
Vitality of Seeds.....	1843	2	0 7
Vitality of Seeds.....	1844	7	0 0
Marine Zoology of Cornwall.....	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mor- tality in York	20	0	0
Earthquake Shocks	1843	15	14 8
	<u>£830</u>	<u>9</u>	<u>9</u>

1846.

British Association Catalogue of Stars	1844	211	15 0
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	£	s.	d.
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1839.....	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials.....	60	0	0
Researches in Asphyxia.....	6	16	2
Examination of Fossil Shells.....	10	0	0
Vitality of Seeds	1844	2	15 10
Vitality of Seeds	1845	7	12 3
Marine Zoology of Cornwall.....	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura	1844	25	0 0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons	1844	8	19 3
Varieties of the Human Race	1844	7	6 3
Statistics of Sickness and Mor- tality in York	12	0	0
	<u>£685</u>	<u>16</u>	<u>0</u>

1847.

Computation of the Gaussian Constants for 1839	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall ...	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	<u>£208</u>	<u>5</u>	<u>4</u>

1848.

Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants.....	15	0	0
	<u>£275</u>	<u>1</u>	<u>8</u>

1849.

Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants.....	5	0	0
Registration of Periodical Phe- nomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	<u>£159</u>	<u>19</u>	<u>6</u>

1850.

Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves ...	50	0	0

	£	s.	d.
Periodical Phenomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	<u>£345</u>	<u>18</u>	<u>0</u>

1851.

Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	<u>£391</u>	<u>9</u>	<u>7</u>

1852.

Maintaining the Establishment at Kew Observatory (including balance of grant for 1850) ...	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations ...	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Anne- lida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	<u>£304</u>	<u>6</u>	<u>7</u>

1853.

Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Anne- lida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	<u>£205</u>	<u>0</u>	<u>0</u>

1854.

Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phe- nomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	<u>£380</u>	<u>19</u>	<u>7</u>

1855.

Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	<u>£480</u>	<u>16</u>	<u>4</u>

£ s. d.

1856.

Maintaining the Establishment at

Kew Observatory:—

1854.....£ 75	0	0
1855.....£500	0	0
	<u>575</u>	<u>0</u> <u>0</u>

Strickland's Ornithological Syno-

nymys	100	0	0
Dredging and Dredging Forms...	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phe- nomena	10	0	0
Propagation of Salmon	10	0	0
	<u>£734</u>	<u>13</u>	<u>9</u>

1857.

Maintaining the Establishment at

Kew Observatory	350	0	0
Earthquake Wave Experiments..	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar..	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products im- ported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	<u>£507</u>	<u>15</u>	<u>4</u>

1858.

Maintaining the Establishment at

Kew Observatory	500	0	0
Earthquake Wave Experiments..	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida...	25	0	0
Experiments on the production of Heat by Motion in Fluids...	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	<u>£618</u>	<u>18</u>	<u>2</u>

1859.

Maintaining the Establishment at

Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	<u>£684</u>	<u>11</u>	<u>1</u>

1860.	£	s.	d.
Maintaining the Establishment of Kew Observatory.....	500	0	0
Dredging near Belfast.....	16	6	0
Dredging in Dublin Bay.....	15	0	0
Inquiry into the Performance of Steam-vessels.....	124	0	0
Explorations in the Yellow Sandstone of Dura Den.....	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals.....	25	0	0
Researches on the Growth of Plants.....	10	0	0
Researches on the Solubility of Salts.....	30	0	0
Researches on the Constituents of Manures.....	25	0	0
Balance of Captive Balloon Accounts.....	1	13	6
	£1241	7	0

1861.	£	s.	d.
Maintaining the Establishment of Kew Observatory.....	500	0	0
Earthquake Experiments.....	25	0	0
Dredging North and East Coasts of Scotland.....	23	0	0
Dredging Committee:—			
1860..... £50 0 0	72	0	0
1861..... £22 0 0			
Excavations at Dura Den.....	20	0	0
Solubility of Salts.....	20	0	0
Steam-vessel Performance.....	150	0	0
Fossils of Lesmahago.....	15	0	0
Explorations at Uriconium.....	20	0	0
Chemical Alloys.....	20	0	0
Classified Index to the Transactions.....	100	0	0
Dredging in the Mersey and Dee.....	5	0	0
Dip Circle.....	30	0	0
Photoheliographic Observations.....	50	0	0
Prison Diet.....	20	0	0
Gauging of Water.....	10	0	0
Alpine Ascents.....	6	5	1
Constituents of Manures.....	25	0	0
	£1111	5	10

1862.	£	s.	d.
Maintaining the Establishment of Kew Observatory.....	500	0	0
Patent Laws.....	21	6	0
Mollusca of N.-W. America.....	10	0	0
Natural History by Mercantile Marine.....	5	0	0
Tidal Observations.....	25	0	0
Photoheliometer at Kew.....	40	0	0
Photographic Pictures of the Sun.....	150	0	0
Rocks of Donegal.....	25	0	0
Dredging Durham and Northumberland.....	25	0	0
Connexion of Storms.....	20	0	0
Dredging North-East Coast of Scotland.....	6	9	6
Ravages of Teredo.....	3	11	0
Standards of Electrical Resistance.....	50	0	0
Railway Accidents.....	10	0	0

	£	s.	d.
Balloon Committee.....	200	0	0
Dredging Dublin Bay.....	10	0	0
Dredging the Mersey.....	5	0	0
Prison Diet.....	20	0	0
Gauging of Water.....	12	10	0
Steamships' Performance.....	150	0	0
Thermo-Electric Currents.....	5	0	0
	£1293	16	6

1863.	£	s.	d.
Maintaining the Establishment of Kew Observatory.....	600	0	0
Balloon Committee deficiency..	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa.....	25	0	0
Coal Fossils.....	20	0	0
Herrings.....	20	0	0
Granites of Donegal.....	5	0	0
Prison Diet.....	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland.....	50	0	0
Dredging North-east coast of Scotland.....	25	0	0
Dredging Northumberland and Durham.....	17	3	10
Dredging Committee superintendence.....	10	0	0
Steamship Performance.....	100	0	0
Balloon Committee.....	200	0	0
Carbon under pressure.....	10	0	0
Volcanic Temperature.....	100	0	0
Bromide of Ammonium.....	8	0	0
Electrical Standards.....	100	0	0
— Construction and distribution.....	40	0	0
Luminous Meteors.....	17	0	0
Kew Additional Buildings for Photoheliograph.....	100	0	0
Thermo-Electricity.....	15	0	0
Analysis of Rocks.....	8	0	0
Hydroids.....	10	0	0
	£1608	3	10

1864.	£	s.	d.
Maintaining the Establishment of Kew Observatory.....	600	0	0
Coal Fossils.....	20	0	0
Vertical Atmospheric Movements.....	20	0	0
Dredging Shetland.....	75	0	0
Dredging Northumberland.....	25	0	0
Balloon Committee.....	200	0	0
Carbon under pressure.....	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks.....	10	0	0
Hydroids.....	10	0	0
Askham's Gift.....	50	0	0
Nitrite of Amyle.....	10	0	0
Nomenclature Committee.....	5	0	0
Rain-Gauges.....	19	15	8
Cast Iron Investigation.....	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays.....	45	0	0
Luminous Meteors.....	20	0	0
	£1289	15	8

1865.

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ADDRESS

OF

JOHN PHILLIPS,

M.A. OXON.; LL.D. DUBLIN; F.R.S.; F.G.S.; ETC.

ASSEMBLED for the third time in this busy centre of industrious England, amid the roar of engines and the clang of hammers, where the strongest powers of nature are trained to work in the fairy chains of art, how softly falls upon the ear the accent of Science, the friend of that art, and the guide of that industry! Here, where Priestley analyzed the air, and Watt obtained the mastery over steam, it well becomes the students of nature to gather round the standard which they carried so far into the fields of knowledge. And when, on other occasions, we meet in quiet colleges and Academic halls, how gladly welcome is the union of fresh discoveries and new inventions with the solid and venerable truths which are there treasured and taught. Long may such union last; the fair alliance of cultivated thought and practical skill; for by it labour is dignified and science fertilized, and the condition of human society exalted!

Through this happy combination of science and art, the young life of the British Association—one-third of a century—has been illustrated by discoveries and enriched by useful inventions in a degree never surpassed. How else could we have gained that knowledge of the laws of nature which has added to the working strength of a thousand millions of men the mightier power of steam*, extracted from the buried ruins of primeval forests their treasured elements of heat and light and colour, and brought under the control of the human finger, and converted into a messenger of man's gentlest thoughts, the dangerous mystery of the lightning†?

How many questions have we asked—not always in vain—regarding the constitution of the earth, its history as a planet, its place in creation;—now probing with sharpened eyes the peopled space around—peopled with a thousand times ten thousand stars;—now floating above the clouds in colder and clearer air;—now traversing the polar ice—the desert sand—the virgin forest—the unconquered mountain;—now sounding the depths of the ocean, or diving into the dark places of the earth. Everywhere curiosity, every-

* The quantity of coal dug in Great Britain in the year 1864 appears by the returns of Mr. R. Hunt to have been 92,787,873 tons. This would yield, if employed in steam-engines of good construction, an amount of available force about equal to that of the whole human race. But in the combustion of coal not less than ten times this amount of force is actually set free—nine-tenths being at present unavailable, according to the statement of Sir William Armstrong, in his Address to the Meeting at Newcastle in 1863.

† The definite magnetic effect of an electrical current was the discovery of Oersted in 1819; Cooke and Wheatstone's patent for an Electric Telegraph is dated in 1837; the first message across the Atlantic was delivered in 1858. *Tantæ molis erat.*

where discovery, everywhere enjoyment, everywhere some useful and therefore some worthy result. Life in every form, of every grade, in every stage; man in every clime and under all conditions; the life that now surrounds us, and that which has passed away;—these subjects of high contemplation have been examined often, if not always, in the spirit of that philosophy which is slowly raising, on a broad security of observed facts, sure inductions, and repeated experiments, the steady columns of the temple of physical truth.

Few of the great branches of the study of nature on which modern philosophy is intent were left unconsidered in the schools of Athens; hardly one of them was or indeed could be made the subject of accurate experiment. The precious instruments of exact research—the measures of time, and space, and force, and motion—are of very modern date. If instead of the few lenses and mirrors of which traces appear in Greek and Roman writers*, there had been even the first Galilean or the smallest Newtonian telescope in the hands of Hipparchus, Eratosthenes, or Ptolemy, would it have been left to their remote successors to be still struggling with the elements of physical astronomy, and waiting with impatience till another quarter of a century shall have rolled away and given us one more good chance of measuring the distance of the Sun by the transit of Venus? Had such instruments as Wheatstone's Chronoscope been invented, would it have been left to Foucault to condense into his own apartment an experimental proof of the velocity of light, and within a tract of thirty feet to determine the rate of its movement through all the vast planetary space of millions and thousands of millions of miles, more exactly than had been inferred by astronomers from observations of the satellites of Jupiter†? By this experiment the velocity of light appears to be less, sensibly less, than was previously admitted; and this conclusion is of the highest interest. For, as by assuming too long a radius for the orbit of Jupiter the calculated rate of light-movement was too great; so now by employing the more exact rate and the same measures of time we can correct the estimated distance of Jupiter and all the other planets from the sun. We have in fact a really independent measure of planetary space; and it concurs with observations of the parallax of Mars, in requiring a considerable reduction of the assumed diameters of the planetary paths. The distance of the earth from the sun must be reduced from above ninety-five to less than ninety-three millions of miles, and by this scale the other space-measures of the solar system, excepting the diameter of the earth and the distance and diameter of the moon, may be corrected‡.

* The effect of lenses or globes of glass or crystal (*ὕαλος*) in collecting the solar rays to a point are familiarly referred to by Aristophanes in the *Nubes*, 766; and the ornamental use of convex and concave reflectors is known by the curious discussions in the IVth Book of Lucretius.

† Fizeau performed experiments on the velocity of light between Suresnes and the Butte Montmartre, by means of the oxyhydrogen light, reflected back in its own path.

The space was 28,324 feet Engl. Twice this distance was traversed in $\frac{1}{18,000}$ of a second = 167,528 geogr. miles in a second. From observations of Jupiter's satellites Delambre inferred 167,976 miles, Struve 166,096. The experiment of M. Foucault gives 298,000,000 metres = 160,920 geogr. miles.

‡ Estimates of the earth's distance from the sun have varied much. Cassini and Flamsteed, using observations of the parallax of Mars, ascribe to it 10,000 or 11,000 diameters of the earth = 79 or 89 millions of miles. Huyghens estimated it at 12,000 = 95 millions of miles. In 1745, Buffon reported it as the common opinion of astronomers at 30 millions of leagues (Fr.) = 90 millions miles (Engl.), but after the transit of Venus

The light and heat which are emitted from the sun reach the earth without great diminution by the absorptive action of the atmosphere; but the waste of heat from the surface of our planet through radiation into space is prevented, or rather lessened by this same atmosphere. Many transparent bodies admit freely heat-rays derived from a source of high temperature, but stop the rays which emanate from bodies only slightly warmed. The atmosphere possesses this quality in a remarkable degree, and owes it to the presence of diffused water and vapour; a fact which Dr. Tyndall has placed in the clear light of complete and varied experiment*. The application of this truth to the history of the earth and of the other planets is obvious. The vaporous atmosphere acts like warm clothing to the earth. By an augmented quantity of vapour dissolved, and water suspended in the air, the waste of surface-heat of the earth would be more impeded; the soil, the water, and the lower parts of the atmosphere would grow warmer; the climates would be more equalized; the general conditions more like what has been supposed to be the state of land, sea, and air during the geological period of the Coal-measures.

Such an augmentation of the watery constituents in the atmosphere would be a natural consequence of that greater flow of heat from the interior, which by many geologists, mathematicians, and chemists is supposed to have happened in the earlier periods of the history of the earth.

By the same considerations we may understand how the planet Mars, which receives not half so much heat from the sun† as the earth does, may yet enjoy, as in fact it seems to enjoy, nearly a similar climate, with snows alternately gathering on one or the other of its poles, and spreading over large spaces around, but not, apparently, beyond the latitude of 50° or 40° ; the equatorial band of 30° or 40° north or south being always free from snow-masses bright enough and large enough to catch the eye of the observer. Mars may therefore be inhabited, and we may see in the present state of this inquiry reason to pause before refusing the probability of any life to Jupiter and even more distant planets.

The history of suns and planets is in truth the history of the effects of light and heat manifested in them, or emanating from them. Nothing in the universe escapes their influence; no part of space is too distant to be penetrated by their energy; no kind of matter is able to resist their transforming agency. Many if not all the special forces which act in the particles of matter are found to be reducible into the general form of heat; as this is convertible and practically is converted into proportionate measures of special energy. Under this comprehensive idea of convertibility of force, familiar to us now by the researches of Joule‡, the reasonings of Grove§ and Helmholtz, and the theorems of Rankine||, it has been attempted by Mayer, Waterston, and Thomson¶ to assign a cause for the maintenance of the heat-giving power of the sun in the appulse of showers of aërolites and small

in 1769, he allowed 33 millions. Such was the effect of that now supposed erroneous experiment on the opinions of astronomers. (*Epoques de la Nature.*)

* *Proc. of Roy. Soc.* 1861. The Rumford Medal was adjudged to Dr. Tyndall in 1864.

† The proportion is about $\frac{1}{231}$ according to the received measure of the mean distance.

‡ *Phil. Mag.* 1843; Reports of the British Association, 1845; Trans. of the Royal Society, 1850.

§ Grove on the Correlation of Physical Forces, 1846.

|| Rankine, Trans. of the Royal Society of Edinburgh, 1850-51; *Phil. Trans.* 1854.

¶ Communication to the Royal Society of Edinburgh, 1854.

masses of matter, and the extinction of their motion on the surface of the luminary. By calculations of the same order, depending on the rate of radiation of heat into space, the past antiquity of the earth and the future duration of sunshine have been expressed in thousands or millions of centuries*. In like manner the physical changes on the sun's disk, by which portions of his darkly heated body become visible through the luminous photosphere, have been connected, if not distinctly as a cause, certainly as a coincident phenomenon, with particular magnetic disturbances on the surface of the earth; the solar spots and the magnetic deflections concurring in periods of maxima and minima of ten or eleven years' duration. Thus even these aberrant phenomena become part of that amazing system of periodical variation which Sabine and his fellow-labourers, British, French, German, Russian, and American, have established by contemporaneous observation over a large part of the globe†.

With every change in the aspect and position of the sun, with every alteration in the place and attitude of the moon, with every passing hour, the magnetism of the earth submits to regular and calculable deviation. Through the substance of the ground, and across the world of waters, Nature, ever the beneficent guide to Science, has conveyed her messages and executed her purposes, by the electric current, before the discovery of Oersted and the magical inventions of Wheatstone revealed the secret of her work.

Even radiant light in the language of the new Philosophy is conceived of by Maxwell‡ as a form of electro-magnetic motion. And thus the imponderable, all-pervading powers, by which molecular energy is excited and exchanged, are gathered into the one idea of restless activity among the particles of matter:—

. . . æterno percita motu :

ever-moving and being moved, elements of a system of perpetual change in every part, and constant preservation of the whole.

What message comes to us with the light which springs from the distant stars, and shoots through the depths of space to fall upon the earth after tens, or hundreds, or thousands of years? It is a message from the very birthplace of light, and tells us what are the elementary substances which have influenced the refraction of the ray. Spectral analysis, that new and powerful instrument of chemical research for which we are indebted to Kirchhoff, has been taught by our countrymen to scrutinize not only planets and stars, but even to reveal the constitution of the nebulae, those mysterious masses out of which it has been thought new suns and planets might be evolved—nursing-mothers of the stars. For a time, indeed, the resolution

* Professor Thomson assigns to the sun's heat, supposing it to be maintained by the appulse of masses of matter, a limit of 300,000 years; and to the period of cooling of the earth from universal fusion to its actual state, 98 million years. These are the lowest estimates sanctioned by any mathematician.

† Among the interesting researches which have been undertaken on the subject of the spots, may be mentioned those of Wolf (*Comptes Rendus*, 1859), who finds the number and periodicity of the spots to be dependent on the position of Venus, the Earth, Jupiter, and Saturn. Stewart has made a special study of the relation of the spots to the path of Venus (*Proc. of the Roy. Soc.* 1864); and Chacornac is now engaged in unfolding his conception of the spots as the visible effect of volcanic excitement. The peculiar features of the solar surface are under examination by these and other good observers; such as Dawes, Nasmyth, Secchi, Stone, Fletcher, Howlett, and Lockyer.

‡ *Proc. of Roy. Soc.* 1864. The elder Herschel appears to have regarded the light of the sun and of the fixed stars as perhaps the effect of an electro-magnetic process—a perpetual aurora.

of some nebulae, by the giant mirror of Lord Rosse, afforded ground for opposing the speculation of Herschel and the reasoning of Laplace, which required for their very starting-point the admission of the existence of thin gaseous expansions, with or without points or centres of incipient condensation, with or without marks of internal movement. The latest results, however, of spectral analysis of stars and nebulae by Mr. Huggins and Professor W. A. Miller, have fairly restored the balance. The nebulae are indeed found to have in some instances stellar points, but they are not stars; the whole resembles an enormous mass of luminous gas, with an interrupted spectrum of three lines, probably agreeing with nitrogen, hydrogen, and a substance at present unknown*. Stars tested by the same accurate hands are found to have a constitution like that of our own Sun, and, like it, to show the presence of several terrestrial elements—as sodium, magnesium, iron, and very often hydrogen. While in the Moon and Venus no lines whatever are found due to an atmosphere, in Jupiter and Saturn, besides the lines which are identical with some produced in our own atmosphere, there is one in the red, which may be caused by the presence of some unknown gas or vapour. Mars is still more peculiar, and enough is ascertained to discountenance the notion of his redness being due to a peculiarity of the soil†.

To aid researches into the condition of celestial bodies, the new powers of light, discovered by Niepce, Daguerre, and Talbot, have been employed by Bond, Draper, De la Rue, and other astronomers. To our countryman, in particular, belongs the honour of successful experiments on the rose-coloured flames which extend from certain points of the sun's border during an eclipse; as well as of valuable contributions through the same agency to that enlarged survey of the physical aspect of the moon, which, since 1852, the Association has striven to promote. By another application of the same beautiful art, in connexion with clock-work, the momentary changes of magnetic force and direction, the variations of temperature, the fluctuations of atmospheric pressure, the force of the wind, the fall of rain, the proportion of ozone in the air, are registered in our observatories; and thus the inventions of Ronalds and his successors have engaged the solar rays in measuring and comparing contemporaneous phenomena of the same order over large parts of the globe—phenomena some of which are occasioned by those very rays.

As we ascend above the earth, heat, moisture, and magnetic force decrease, the velocity of wind augments, and the proportion of oxygen and nitrogen remains the same. The decrease of heat as we rise into the air is no new subject of inquiry, nor have the views respecting it been very limited or very accordant. Leslie considered it mathematically in relation to pressure; Humboldt gave the result of a large inquiry at points on the earth's surface, unequally elevated above the sea; and finally, Mr. Glaisher and Mr. Coxwell, during many balloon ascents to the zones of life-destroying cold, far above our mountain tops, have obtained innumerable data, in all seasons of the year, through a vast range of vertical height. The result is to show much more rapid decrease near the earth, much slower decrease at great elevations; thus agreeing in general with the decrease of density, and yet throwing no discredit on the determinations of Humboldt, which do not refer to the free atmospheric ocean, but to the mere borders of it where it touches the earth, and is influenced thereby‡.

* Proc. Roy. Soc. and Phil. Trans. 1864.

† Phil. Trans. 1864.

‡ Reports of the British Association for 1862, 1863, 1864.

The proportion of carbonic acid gas in the atmosphere at great heights is not yet ascertained: it is not likely to be the same as that generally found near the earth; but its proportion may be more constant, since in those regions it is exempt from the influence of the actions and reactions which are always in progress on the land and in the water, and do not necessarily compensate one another at every place and at every moment.

Other information bearing on the constitution of the atmosphere comes to us from the auroral beams and other meteoric lights known as shooting-stars. For some of these objects not only appear at heights of ten, fifty, and one hundred or more miles above the earth, but at the height of fifty miles it is on record that shooting-stars or fire-balls have left waving trains of light, whose changes of form were in seeming accordance to varying pressure in the elevated and attenuated atmosphere*.

Researches of every kind have so enriched meteorology since our early friend, Professor J. Forbes, printed his suggestive reports on that subject, and so great have been the benefits conferred on it by the electric telegraph, that at this moment in M. Leverrier's observatory at Paris, and the office so lately presided over by Admiral FitzRoy in London, the messages are arriving from all parts of Europe to declare the present weather, and furnish grounds for reasonable expectation of the next probable change. Hardly now within the seas of Europe can a cyclone begin its career of devastation, before the warning signal is raised in our sea-ports, to restrain the too confident sailor. The gentle spirit which employed this knowledge in the cause of humanity has passed away, leaving an example of unselfish devotion, in a work which must not fail through any lack of energy on the part of this Association, the Royal Society, or the Government. We must extend these researches and enlarge these benefits by the aid of the telegraph bringing the ends of the world together. Soon may that thread of communication unite the two great sections of the Anglo-Saxon race, and bring and return through the broad Atlantic the happy and mutual congratulations for peace restored and friendships renewed.

The possible combinations of force by which, in the view we have been considering, the characteristic forms and special phenomena of solid, liquid, and gaseous matter are determined, may be innumerable. Practically, however, they appear to be limited, as natural products, to less than one thousand distinguishable compounds, and less than one hundred † elementary substances. Of these elements the most prevalent are few on the earth; as of gases, oxygen, hydrogen, nitrogen; of solids, silicon, calcium, magnesium, sodium, iron; and it is interesting to learn by analysis of the light of stars and planets, that these substances, or some of them, are found in most of the celestial objects yet examined, and that, except in one or two instances, no other substances have been traced therein. Even the wandering meteoric stones, which fall from their courses, and are examined on the earth, betray only well-known mineral elements, though in the manner in which these are combined, some differences appear, which by chemical research and the aid of transparent sections Professor Maskelyne and Mr. Sorby are engaged in studying and interpreting‡.

* This is the result of a careful discussion made by myself of observations on a meteor seen from Rouen to Yorkshire, and from Cornwall to Kent, Jan. 7, 1856.

† At the present moment the number of "elementary substances" is sixty-one.

‡ Professor Maskelyne has made a convenient classification of the large collection of meteorites in the British Museum, under the titles of "*Aërolite* or *Meteoric Stone*;" "*Aërosiderite* or *Meteoric Iron*;" and "*Aërosiderolites*," which includes the intervening

By the labours of Lavoisier and his contemporaries, Chemistry acquired a fixed logic and an accurate nomenclature. Dalton and the great physicists of the early part of this century gave that law of definite combination by proportionate weights of the elements which is for chemistry what the law of gravitation is for celestial mechanics. A great expansion of the meaning of the atomic theory took place, when Mitscherlich announced his views of isomorphous, isomeric, and dimorphous bodies. For thus it came gradually to appear that particular forces resided in crystals in virtue of their structure, lay in certain directions, and exhibited definite physical effects, if the chemical elements, without being the same, were combined in similar proportions, and aggregated into similar crystals. Some years later, ozone was discovered by Schönbein, and it concurred with a few other allotropic substances in reviving, among philosophic chemists, the inquiry as to the relative situation of the particles in a compound body, and the effects of such arrangements: an idea which had been expressed by Dalton in diagrams of atoms, and afterwards exercised the ingenuity of Exley, MacVicar, and others*.

Everything connected with this view of the modification of physical properties by the arrangement of the particles—whether elementary or compound—is of the highest importance to mineralogy, a branch of study by no means so much in favour even with chemists as its own merits and its collateral bearings might justly deserve. Yet it is in a great measure by help of this branch of study that the opinions now current regarding metamorphism of rocks *in situ*, and the formation of mineral veins, must acquire that solid support and general consent which at present they do not possess. Crystals, indeed, whether regarded as to their origin in nature, their fabrication by art, or their action on the rays of light, the waves of heat and sound, and the distribution of electricity, have not been neglected by the Association or its members. In one of the earliest Reports, Dr. Whewell calls attention to the state of crystallographical theory, and to the artificial production of crystals; and in another Report, Professor Johnston notices epigene and pseudomorphous crystallization; and for many years, at almost every meeting, new and brilliant discoveries in the action of crystals on light were made known by Brewster†, and compared with the undulatory theory by Herschel, MacCullagh, Airy, Hamilton, Whewell, Powell, Challis, Lloyd, and Stokes.

The unequal expansion of crystals by heat, in different directions, first observed by Mitscherlich, has been carefully examined in the cases of sulphate and carbonate of lime by Professor W. H. Miller‡, who has also considered their elasticity, originally measured in different relations to the axis by Savart. These and many other interesting relations of crystals have

varieties. Mr. Sorby, whose latest results are unpublished, but will be communicated to the Royal Society, is of opinion that the substance of meteorites has undergone changes due to physical conditions in some ancient period not now to be paralleled on our planet, or on the moon, but rather to be looked for only in the immediate neighbourhood of the sun. Professor Haidinger has also made a special study of meteorites.

* Dalton, Chemistry, vol. i. 1808. A clear view of the simpler applications of Dalton's ideas is given by the illustrious author in Daubeny's Treatise on the Atomic Theory, 1850. Exley, Nat. and Exp. Philosophy, 1829. MacVicar, Rep. Brit. Assoc. 1855; Trans. Roy. Soc. Edinb., &c.

† "Sir David Brewster must be considered as in a degree the creator of the science which studies the mutual dependence of optical properties and crystalline forms." (Whewell, in Report on Mineralogy, Brit. Assoc. 1832, p. 336.)

‡ Rep. Proc. 1837, pp. 43, 44.

been attended to; but the Association has not yet succeeded in obtaining a complete digest of the facts and theories connected with the appearance of crystals in nature—in the fissures of rocks; in the smaller cavities of rocks; in the solid substance or liquid contents of other crystals. Such an inquiry, however, it did earnestly demand, and some steps have been taken by our own chemists, mineralogists, and geologists. But more abundant information on this class of subjects is still needed, even after the admirable contributions and recent discoveries of Bischof, Delesse, and Daubrée*.

Within our Association-period both the nomenclature of chemistry and the conception of the atomic theory have received not indeed a change, but such an addition to its ordinary expression as the more general language and larger meaning of Algebra have conferred on common arithmetical values. The theory of compound radicals, as these views of Liebig, Dumas, and Hofmann may be justly termed, embraces the consideration of groups of elements united in pairs by the ordinary law, these groups being for the purpose in hand treated as single elements of combination. The nomenclature which attempts in ordinary words to express these relations grows very unmanageable even in languages more easily capable of polysyllabic combinations than ours; but symbols of composition—the true language of chemistry—are no more embarrassed in the expression of these new ideas than are the mathematical symbols which deal with operations of much greater complexity on quantities more various and more variable†. The study of these compound radicals comes in aid of experimental research into those numerous and complex substances which appear as the result of chemical transformations in organic bodies. Thus in some instances the very substances have been recomposed by art which the vital processes are every moment producing in nature; in others the steps of the process are clearly traced; in all the changes become better understood through which so great a variety of substances and structures are yielded by one circulating fluid; and the result is almost a new branch of animal and vegetable physiology, not less important for the health of mankind than essential to the progress of scientific agriculture.

The greater our progress in the study of the economy of nature, the more she unveils herself as one vast whole; one comprehensive plan; one universal rule, in a yet unexhausted series of individual peculiarities. Such is the aspect of this moving, working, living system of force and law: such it has ever been, if we rightly interpret the history of our own portion of this rich inheritance of mind, the history of that Earth from which we spring, with which so many of our thoughts are coordinated, and to which all but our thoughts and hopes will again return.

How should we prize this history! and exult in the thought that in our own days, within our own memories, the very foundations of the Series of Strata, deposited in the beginning of time, have been explored by our living friends, our Murchison and Sedgwick, while the higher and more complicated parts of the structure have been minutely examined by our Lyell, Forbes, and Prestwich‡! How instructive the history of that long series of inhabi-

* Bischof, *Chemical Geology* (published by the Cavendish Society, 1856).

Delesse, *Etudes sur le Métamorphisme*, 1858, and other works.

Daubrée, *Sur la Relation des Sources Thermales des Plombières, avec les Filons Métallifères et la Formation des Zeolithes*, 1858, and other works.

† On the Nomenclature of Organic Compounds, by Dr. Daubeny. Reports of British Association, 1851.

‡ The investigations of Murchison and Sedgwick in the Cambrian and Silurian Strata began in 1831; the views of Sir C. Lyell on Tertiary periods were made known in 1829.

tants which received in primeval times the gift of life, and filled the land, sea, and air with rejoicing myriads, through innumerable revolutions of the planet, before in the fulness of time it pleased the Giver of all good to place man upon the Earth, and bid him look up to Heaven.

Wave succeeding wave, the forms of ancient life sweep across the ever-changing surface of the earth; revealing to us the height of the land, the depth of the sea, the quality of the air, the course of the rivers, the extent of the forest, the system of life and death—yes, the growth, decay, and death of individuals, the beginning and ending of races, of many successive races of plants and animals, in seas now dried, on sand-banks now raised into mountains, on continents now sunk beneath the waters.

Had that series a beginning? Was the earth ever uninhabited, after it became a globe turning on its axis and revolving round the sun? Was there ever a period since land and sea were separated—a period which we can trace—when the land was not shaded by plants, the ocean not alive with animals? The answer, as it comes to us from the latest observation, declares that in the lowest deposits of the most ancient seas in the stratified crust of the globe, the monuments of life remain. They extend to the earliest sediments of water, now in part so changed as to appear like the products of fire. What life? Only the simpler and less specially organized fabrics have as yet rewarded research among these old Laurentian rocks—only the aggregated structures of Foraminifera have been found in what, for the present at least, must be accepted as the first deposits of the oldest sea. The most ancient of all known fossils, the *Eozoon Canadense* of Sir W. Logan, is of this low, we may even say lowest, type of animal organization.

Then step by step we are guided through the old Cambrian and Silurian systems, rich in Trilobites and Brachiopoda, the delights of Salter and Davidson; with Agassiz and Miller and Egerton we read the history of the strange old fishes of the Devonian rocks; Brongniart, and Göppert, and Dawson, and Binney, and Hooker unveil the mystery of the mighty forests now converted to coal; Mantell and Owen and Huxley restore for us the giant reptiles of the Lias, the Oolite, and the Wealden; Edwards and Wright almost revive the beauteous corals and echinodermata; which with all the preceding tribes have come and gone before the dawn of the later periods, when fragments of mammoths and hippopotami were buried in caves and river sediments to reward the researches of Cuvier and Buckland, Prestwich and Christy, Lartet and Falconer.

And what is the latest term in this long series of successive existence? Surely the monuments of ever-advancing art—the temples whose origin is in caverns of the rocks; the cities which have taken the place of holes in the ground, or heaps of stones and timber in a lake; the ships which have outgrown the canoe, as *that* was modelled from the floating trunk of a tree, are sufficient proof of the late arrival of man upon the Earth, after it had undergone many changes and had become adapted to his physical, intellectual, and moral nature.

Compared with the periods which elapsed in the accomplishment of these changes, how short is the date of those yet standing monoliths, cromlechs, and circles of unhewn stone which are the oldest of human structures raised in Western Europe, or of those more regular fabrics which attest the early importance of the monarchs and people of Egypt, Assyria, and some parts of America! Yet tried by monuments of natural events which happened within the age of man, the human family is old enough in Western Europe to have been sheltered by caverns in the rocks, while herds of reindeer roamed in

Southern France*, and bears and hyenas were denizens of the South of England†. More than this, remains of the rudest human art ever seen are certainly found buried with and are thought to belong to races who lived contemporaneously with the mammoth and rhinoceros, and experienced the cold of a Gallic or British winter, from which the woolly covering of the wild animals was a fitting protection.

Our own annals begin with the Kelts, if indeed we are entitled to call by that historic name the really separate nations, Belgian, Iberian, and Teutonic, whom the Roman writers recognize as settlers in Britain‡; settlers among a really earlier family, our rudest and oldest forefathers, who may have been, as they thought themselves to be, the primitive people of the land§. But beyond the *Kελταί* who occupied the sources of the Danube and the slopes of the Pyrenees, and were known to Rome in later days, there was present to the mind of the father of Grecian history a still more western race, the Cynetæ, who may perhaps be supposed the very earliest people of the extreme west of the continent of Europe. Were those the people, the first poor pilgrims from the East, whose footsteps we are slowly tracing in the valleys of Picardy and the south of England, if not on the borders of the lakes of Switzerland? Are their kindred still to be found among the Rhætian Alps and the Asturian cliffs, if not amid the wilds of Connemara, pressed into those mountainous recesses by the legions of Rome, the spear of the Visigoth, and the sword of the Saxon? Or must we regard them as races of an earlier type, who had ceased to chip flints before the arrival of Saxon, or Goth, or Kelt, or Cynetian? These questions of romantic interest in the study of the distribution and languages of the families of man are part of a large circle of inquiry which finds sympathy in several of our Sections, especially those devoted to Zoology, Physiology, and Ethnology. Let us not expect or desire for them a very quick, or, at present, a very definite settlement. Deep shadows have gathered over all the earlier ages of mankind, which perhaps still longer periods of time may not avail to remove. Yet let us not undervalue the progress of ethnological inquiry, nor fail to mark how, within the period to which our recollections cling, the revelations of early Egypt have been followed by a Chronology of the ancient kingdoms on the Tigris and Euphrates, through the same rigorous study of language. Thus has our Rawlinson added another page to the brilliant discoveries of Young and Champollion, Lepsius and Rosellini.

Nor, though obtained in a different way, must we forget the new knowledge of a people nearer home, which the philosophic mind of Keller has opened to us among his native mountains. There, on the borders of the Alpine lakes, before the great Roman general crossed the Rhone, lived a people older than the Helvetians; whose rude lives, passed in hunting and fishing, were nevertheless marked by some of the many inventions which everywhere, even in the most unfavourable situations, accompany the least civilized of mankind. Implements of stone and pottery of the rudest sort belong to the earliest of these people; while ornamented iron weapons of war, and innumerable other fabrics in that metal, appear about the later habita-

* See the Memoirs of M. Lartet on the Caves of the Dordogne, 1863-64.

† In the caves of Gower, Devon, and Somerset, flint flakes occur with several extinct animals.

‡ Gallic or Belgian on the south-east coast; Iberian in South Wales; German at the foot of the Grampians. (Tacitus, *Vita Agricolæ*.)

§ "Britannicæ pars interior ab iis incolitur, quos natos in insula ipsa memoria proditum dicunt." (Cæsar, v. 12.)

tions, and correspond probably to the period of the true Helvetii, who quitted their home and contended with Cæsar for richer settlements in Gaul. The people of whom these are the traces on almost every lake in Switzerland are recognized as well in the ancient lake-basins of Lombardy and among the Tyrolean Alps, and further on the north side of the mountains; and probably fresh discoveries may connect them with the country of the Sarmatians and the Scythians.

Thus at length is fairly opened, for archæology and palæontology to read, a new chapter of the world's history, which begins in the pleistocene periods of geology, and reaches to the prehistoric ages of man. Did our ancestors really contend, as the poets fancied*, with stones and clubs against the lion and the rhinoceros, and thus expel them from their native haunts, or have they been removed by change of climate or local physical conditions? Was the existence of the hyena and the elephant only possible in Western Europe while a climate prevailed there such as now belongs to Africa or India? and was this period of high temperature reduced in a later time for the elk, reindeer, and musk ox, which undoubtedly roamed over the hills of England and France? If we think so, what a vista of long duration stretches before us, for no such changes of climate can be supposed to have occurred except as the effect of great physical changes, requiring a lapse of many thousands of years. And though we may think such changes of climate not proved, and probably careful weighing of evidence may justify our disbelief, still, if the valleys in Picardy have been excavated since the deposit of the gravel of St. Acheul†, and the whole face of the country has been altered about the caverns of Torquay since they received remains of animals and traces of man‡—how can we admit these facts and yet refuse the time required for their accomplishment? First, let us be sure of the facts, and especially of that main fact upon which all the argument involving immensity of time really turns, viz. the contemporaneous existence of man with the mammoth of the plains and the bear of the caverns. The remains of men are certainly *buried* with those of extinct quadrupeds; but did they *live* in the same days, or do we see relics of different periods gathered into one locality by natural processes of a later date, or confused by the operations of men?

Before replying finally to these questions, further researches of an exact kind are desirable, and the Association has given its aid towards them, both in respect to the old cavern of Kent's Hole, and the newly opened fissure of Gibraltar, from which we expect great results, though the best of our labourers has ceased from his honourable toil§. When these and many other researches are completed, some future Lyell, if not our own great geologist, may add some fresh chapters to the 'Antiquity of Man.'

In judging of this antiquity, in counting the centuries which may have elapsed since smoothed flints fitted with handles of wood were used as chisels and axes by the earliest people of Scandinavia or Helvetia, and flakes of flint were employed to cleanse the skins of the reindeer in the caves of the Dordogne, or stronger tools broke up the ice in the valley of the Somme, we must be careful not to take what is the mark of low civilization for the indication of very remote time. In every country, among every race of men,

* Lucretius, v. 964–1283.

† Prestwich, Transactions of the Royal Society, 1860, and Proc. of Roy. Inst., Feb. 1864.

‡ Pengelly, Reports of the British Association, 1864.

§ The late Dr. Hugh Falconer, whose knowledge of the fossil animals of caves was remarkably exact, took a great share in these examinations.

such rude weapons and tools are used now, or were used formerly. On the banks of the Ohio, no less than on the English hills, mounds of earth, rude pottery, and stone weapons occur in abundance; and indicate similar wants, contrivances, customs, ideas, in different races of men living in different periods. Even when in the same country, as in Switzerland, or England, or Denmark, successive deposits of instruments of stone, bronze, or iron; successive burials of pines, beeches, and oaks; successively extinguished races of elephants, elks, and reindeer, give us a real scale of elapsed time, it is one of which the divisions are not yet valued in years or centuries of years.

Toward a right judgment of the length of this scale of human occupation, two other lines of evidence may be thought worthy of notice; one founded on the anatomical study of the remains of early men, the other on the laws of language. If the varieties of physical structure in man, and the deviations of language from an original type, be natural effects of time and circumstance, the length of time may be in some degree estimated by the amount of the diversities which are observed to have happened, compared with the variation which is now known to be happening. This process becomes imaginary, unless we assume all mankind to have had one local centre, and one original language. Its results must be erroneous, unless we take fully into account the superior fixity of languages which are represented in writing, and the greater tendency to diversity of every kind which must have prevailed in early times, when geographical impediments were aggravated by dissocial habits of life. It appears, however, certain that some differences of language, organization, and habits have separated men of apparently unlike races during periods longer than those which rest on historical facts*.

Ever since the days of Aristotle, the analogy existing among all parts of the animal kingdom, and in a general sense we may say among all the forms of life, has become more and more the subject of special study. Related as all living beings are to the element in which they move and breathe, to the mechanical energies of nature which they employ or resist, and to the molecular forces which penetrate and transform them, some general conformity of structure, some frequently recurring resemblance of function, must be present, and cannot be overlooked. In the several classes this analogy grows stronger, and in the subdivisions of these classes real family affinity is recognized. In the smallest divisions which have this family relation in the highest degree, there seems to be a line which circumscribes each group, within which variations occur, from food, exercise, climate, and transmitted peculiarities. Often one specific group approaches another, or several others, and a question arises whether, though now distinct, or rather distinguishable, they always have been so from their beginning, or will be always so until their disappearance.

Whether what we call species are so many original creations or derivations from a few types or one type, is discussed at length in the elegant treatise of Darwin†, himself a naturalist of eminent rank. It had been often discussed before. Nor will any one think lightly of such inquiries, who remembers the essay of Linnæus, "*De Tulluris orbis incremento*," or the investigations of Brown, Prichard, Forbes, Agassiz, and Hooker regarding the local origin of different species, genera, and families of plants and animals, both on the land and in the sea. Still less will he be disposed to undervalue its importance, when he reflects on the many successive races of living forms more or less resembling our existing quadrupeds, reptiles, fishes, and mollusca, which

* Max Müller on the Science of Language.

† On the Origin of Species, 1859.

appeared to have occupied definite and different parts of the depths of ancient time; as now the tiger and the jaguar, the cayman and the gavial, live on different parts of the terrestrial surface. Is the living elephant of Ceylon the lineal descendant of that mammoth which roamed over Siberia and Europe and North America, or of one of those sub-Himalayan tribes which Dr. Falconer has made known, or was it a species dwelling only in circumpolar regions? Can our domestic cattle, horses and dogs, our beasts of chase and our beasts of prey, be traced back to their source in older types, contemporaries of the Urus, Megaceros, and Hyena on the plains of Europe? If so, what range of variation in structure does it indicate? if not so, by what characters are the living races separated from those of earlier date?

Specific questions of this kind must be answered before the general proposition, that the forms of life are indefinitely variable with time and circumstance, can be even examined by the light of adequate evidence. That such evidence will be gathered and rightly interpreted, I for one neither doubt nor fear; nor will any be too hasty in adopting extreme opinions or too fearful of the final result, who remember how often that which is true has been found very different from that which was plausible, and how often out of the nettles of danger we have plucked the flowers of safety. At the present moment the three propositions which were ever present to the mind of Edward Forbes may be successfully maintained, as agreeing with many observed phenomena; and around them as a basis of classification may be gathered most of the facts and most of the speculations which relate to the history of life*. First, it may be admitted that plants and animals form many natural groups, the members of which have several common characters, and are parted from other groups by a real boundary line, or rather unoccupied space. Next, that each of these groups has a limited distribution in space, often restrained by high mountains or deep seas, or parallels of temperature, within which it has been brought into being. Thirdly, that each group has been submitted to, or is now undergoing, the pressure of a general law, by which its duration is limited in geological time; the same group never reappearing after being removed from the series.

How important, in the view of this and many other questions, is that never-tiring spirit of geographical and maritime discovery, to which through four hundred years Europe has sent her noblest sons and her most famous expeditions; sent them, alas! too often to an early grave. Alas! for Franklin, who carried the magnetic flag into the Icy Sea from which he had already brought trophies to Science! Alas! for Speke, who came home with honour from the head waters of the Nile! Forgotten they can never be, whenever, on occasions like this, we mourn the absence of our bravest and our best; praise, never-ending praise be theirs, while men retain the generous impulse which prompts them to enterprises worthy of their country and beneficial to mankind!

Ἀεὶ σφῶν κλέος ἔσσεται κατ' αἶαν.

If it be asked, what share in the discoveries and inventions of the last thirty-three years is claimed for the British Association; let us answer fearlessly—We had a part in all. In some of them we took the foremost place by the frequency of our discussions, the urgency of our recommendations, the employment of our influence, and the grant of our funds. For others we gave all our strength, to support the Royal Society and other institutions in

* See the remarkable Essay of E. Forbes on the distribution of the existing Fauna and Flora of the British Isles, in *Memoirs of Geol. Survey of Britain*, vol. i. p. 336.

their efforts to accomplish purposes which we approve. In all instances our elastic system responds quickly to pressure, and returns the friendly impulse. If we look back on the work of previous years, it is easy to mark the special action of the Association in fields which hardly could be entered by any other adventurers.

Many of the most valuable labours of which we are now reaping the fruits, were undertaken in consequence of the reports on special branches of Science which appear in the early volumes of our Transactions—reports in which particular data were requested for confirming or correcting known generalizations, or for establishing new ones. Thus a passage in Professor Airy's report on Physical Astronomy* first turned the attention of Adams to the mathematical vision of Neptune; Lubbock's Report on Tides† came before the experimental researches and reductions, which since 1834 have so often engaged the attention of Whewell and Airy and Haughton, with results so valuable and so suggestive of further undertakings. Among these results may be placed additional knowledge of the probable depth of the channels of the sea. For before the desire of telegraphic communication with America had caused the bed of the North Atlantic to be explored by soundings to a depth seldom exceeding three miles, there was reason to conclude from the investigations of Whewell on Cotidal Lines‡ that a depth of nine miles was attained in the South Atlantic, and from the separate computations of Airy and Haughton that a somewhat greater depth occurred in a part of the course of the tide-wave which washes the coast of Ireland§. The greater portion of the sea-bed is within reach of soundings directed by the superior skill and greater perseverance of modern scientific navigators; a depth of six miles is said to have been reached in one small tract of the North Atlantic; depths of nine or ten miles in the deepest channels of the sea are probable from considering the general proportion which is likely to obtain between sea-depths and mountain-tops. Thus the data are gradually being collected for a complete survey of the bed of the sea, including among other things information, at least, concerning the distribution of animal and vegetable life beneath the waters.

Waves—their origin, the mechanism of their motion, their velocity, their elevation, the resistance they offer to vessels of given form, these subjects have been firmly kept in view by the Association, since first Professor Challis|| reported on the mathematical problems they suggest, and Sir J. Robison and Mr. Scott Russell undertook to study them experimentally¶. Out of this inquiry has come a better knowledge of the forms which ought to be given to the 'lines' of ships, followed by swifter passages across the sea, both by sailing vessels and steamers, of larger size and greater lengths than were ever tried before**.

One of the earliest subjects to acquire importance in our thoughts, was the unexplored region of meteorology laid open in Professor J. Forbes's Reports††. Several of the points to which he called attention have been successfully attained. The admirable instruments of Whewell, Osler, and Robinson have replaced the older and ruder anemometers, and are everywhere in full opera-

* Reports of the British Association for 1832, p. 154. Laplace had indeed observed that "the planet Uranus and his satellites, lately discovered, give reason to suspect the existence of some planets not yet observed;" thereby encouraging the search for new discoveries in our own system. (Exp. du Syst. du Monde, 1799, 4to, p. 350.)

† Reports of the British Association, 1832.

‡ Trans. of Roy. Soc. 1833.

§ Trans. of Roy. Irish Acad. 1855. || Reports of the British Association, 1833, 1836.

¶ Ibid. 1837 and following years.

** Ibid. 1840-1843.

†† Ibid. 1832-1840.

tion, to record the momentary variations of pressure, or sum the varying velocities of the wind. No small thanks were due to Mr. Marshall and Mr. Miller* for their enterprise and perseverance in placing rain-gauges and thermometers amidst the peaks of Cumberland and Westmoreland. These experiments are now renewed in both counties and in North Wales; and I hope to hear of similar efforts among the mountains of the West of Ireland and the West of Scotland. Our meteorological instruments of every kind have been improved; our system of photographic registration has spread from Kew into other observatories; and our corresponding member, Professor Dove, has collected into systematic maps and tables the lines and figures which represent annual and monthly climate over every land and sea.

In the same manner, by no sudden impulse or accidental circumstance, rose to its high importance that great system of magnetic observations, on which for more than a quarter of a century the British Association and the Royal Society, acting in concert, have been intent. First, we had Reports on the mathematical theory and experimental researches of magnetism by Christie (1833), Whewell (1835), and Sabine (1835):—afterwards, a magnetic survey of the British Islands†; then, the establishment of a complete observatory at Dublin, with newly arranged instruments, by Dr. Lloyd, in 1838. On all this gathered experience we founded a memorial to Her Majesty's Government, made a grant of £400 from our funds for preliminary expenses, and presented to the Meeting of this Association in Birmingham, in 1839, a Report of progress, signed by Herschel and Lloyd. From that time how great the labour, how inestimable the fruits! Ross sails to the magnetic pole of the south; America and Russia cooperate with our observers at Kew, Toronto, and St. Helena; and General Sabine, by combining all this united labour, has the happiness of seeing results established of which no man dreamed—laws of harmonious variation affecting the magnetic elements of the globe, in definite relation to the earth's movement, the position of the sun and moon, the distribution of temperature, and the situation in latitude and longitude‡.

Our efforts have not been fruitless, whether with Mr. Mallet we make experiments on artificial earth-shocks at Dalkey, or survey the devastations round Vesuvius, or tabulate the records of earthquakes since the beginning of history§; or establish the Kew Observatory as a scientific workshop where new instruments of research are made and proved and set to work||; or dredge the sea with Forbes, and Brady, and Jeffreys¶; or catalogue the stars with Baily**; or investigate electricity with Harris, Ronalds, Thomson,

* Mr. Marshall's observations were made in Patterdale, Mr. Miller's about Wastdale Head. (British Association Reports for 1846, and Royal Society's Transactions, 1850.)

† The survey was begun in Ireland in 1835, by Lloyd, Sabine, and Ross; and completed in England, Wales, and Scotland in 1837, by the same magneticians, assisted by Fox and Phillips. It was repeated in 1857 and following years by Sabine, Lloyd, Welsh, Haughton, Galbraith, and Stoney.

‡ Trans. of the Royal Society for many years; Reports of the British Association, 1840 and following years; Rede Lecture, 1862.

§ British Association Reports; Experiments at Dalkey, 1853; Report on Earthquakes, 1840-1858. See also the excellent communications of M. Perrey to the Memoirs of the Academy of Dijon.

|| The Kew Observatory became a part of the system of the Association in 1842.

¶ See Reports of the Dredging Committees from 1842 to 1864; Nat. Hist. Trans. of Northumberland and Durham; Jeffreys's British Conchology.

** British Association Catalogue of Stars, 1845.

and Jenkin*; or try the action of long-continued heat with Harcourt†: in these and a hundred other directions, our attempts to gain knowledge have brought back new facts and new laws of phenomena, or better instruments for attaining or better methods for interpreting them. Even when we enter the domain of practical art, and apply scientific methods to test a great process of manufacture, we do not fail of success; because we are able to join in united exertion the laborious cultivators of science and the scientific employers of labour.

Am I asked to give an example? Let it be iron, the one substance by the possession of which, by the true knowledge and right use of which, more than by any other thing, our national greatness is supported. What are the ores of iron—what the peculiarities and improvements of the smelting processes—what the quality of the iron—its chemical composition—its strength in columns and girders as cast iron; in rails and boiler plate, in tubes and chains, as wrought iron—what are the best forms in which to employ it, the best methods of preserving it from decay;—these and many other questions are answered by many special Reports in our volumes, bearing the names of Barlow, Mallet, Porter, Fairbairn, Bunsen, Playfair, Percy, Budd, Hodgkinson, Thomson; and very numerous other communications from Lucas, Fairbairn, Cooper, Nicholson, Price, Crane, Hartley, Davy, Mushet, Hawkes, Penny, Scoresby, Dawes, Calvert, Clark, Cox, Hodgkinson, May, Schafhaeutl, Johnston, Clay, and Boutigny. Beyond a question, a reader of such of these valuable documents as relate to the strength of iron, in its various forms, would be far better informed of the right course to be followed in experiments on armour-plated ships and forts to resist assault, and in the construction of ordnance to attack them, than he is likely to be from merely witnessing a thousand trials of the cannon against the target. Anyone who remembers what the iron furnace was forty years ago, and knows its present power of work, or who contrasts the rolling mills and hammers of other days with the beautiful machines which now, with the gentlest motion but irresistible force, compel the strong metal to take up the most delicately moulded form, will acknowledge that, within the period since the British Association began to set itself to the task of reconciling the separated powers of Theory and Experience, there has been a total change in the aspect of each, to the great advantage of both.

Our undertakings have not been fruitless. We attempted what we had well considered, and had the power to accomplish; and we had the more than willing help of competent persons of our own body, the friendly aid of other Institutions, and the sanction of the Government, convinced of the sincerity of our purpose and the wisdom of our recommendations.

The same work is ever before us; the same prudence is always necessary; the same aid is always ready. Great indeed should be our happiness, in reflecting on the many occasions, when the Royal Society in particular, and other Institutions older than our own, have readily placed themselves by our side, to share our responsibility and diminish our difficulties. But for this, our wishes might not always have prevailed; and the horizon of science would not have been so clear as now it is. Of late years, indeed, Societies formed on our model have taken up special parts of our work; and thus to some extent have relieved us of the pressure of communications relating to the practice of particular professions and the progress of some public questions. Not that scientific agriculture, social statistics, or physiology are neglected in our meetings, but that these and

* The latest result of these researches is an instrumental standard of electrical resistance. (Reports of the British Association, 1863-1864.

† Reports of the British Association, 1846-1860.

other practical subjects are found to have more than one aspect, and to require more than one mode of treatment. With us, facts well ascertained, conclusions rightly drawn, will ever be welcome, from whatever quarter of the horizon of science they make their appearance. Whatever societies cultivate these objects, they are our allies, and we will help them, if we may. With pleasure we receive proofs of the good work done in limited districts by the many admirable Field Clubs formed by our countrymen; whether, like those of Tyneside and the Cotswolds, and in this immediate vicinity those of Warwickshire, Worcestershire, and Dudley, they explore the minutest recesses of our hills and glens; or, like the rangers of the Alps, bring us new facts regarding glaciers, ancient climate, and altered levels of land and sea.

By these agreeable gatherings natural history is most favourably commended; and in the activity and enlarged views of the officers who conduct them, the British Association recognizes the qualities by which the vitality of scientific research is maintained, and its benefits diffused among the provincial Institutions of the Empire.

Such, Gentlemen, are some of the thoughts which fill the minds of those, who, like our Brewster, and Harcourt, and Forbes, and Murchison, and Daubeny, stood, anxious but hopeful, by the cradle of this British Association; and who now meet to judge of its strength, and measure its progress. When, more than thirty years ago, this Parliament of science came into being, its first child-language was employed to ask questions of Nature; now, in riper years, it founds on the answers received further and more definite inquiries directed to the same prolific source of useful knowledge. Of researches in science completed, in progress, or in beginning, each of our annual volumes contains some three hundred or more passing notices, or full and permanent records. This digest and monument of our labours is indeed in some respects incomplete, since it does not always contain the narrative or the result of undertakings which we started, or fostered, or sustained; and I own to having experienced on this account once or twice a feeling of regret. But the regret was soon lost in the gratification of knowing that other and equally beneficial channels of publication had been found; and that by these examples it was proved how truly the Association kept to the real purpose of its foundation, "the Advancement of Science," and how heartily it rejoiced in this advancement without looking too closely to its own share in the triumph. Here, indeed, is the stronghold of the British Association. Wherever and by whatever means sound learning and useful knowledge are advanced, there to us are friends. Whoever is privileged to step beyond his fellows on the road of scientific discovery, will receive our applause, and, if need be, our help. Welcoming and joining in the labour of all, we shall keep our place among those who clear the ways and remove the obstacles from the paths of science; and whatever be our own success in the rich fields which lie before us, however little we may now know, we shall prove that in this our day we knew at least the value of knowledge, and joined hearts and hands in the endeavour to promote it.

REPORTS

ON

THE STATE OF SCIENCE.

Report on Dredging among the Channel Isles.
By J. GWYN JEFFREYS, F.R.S.

OUR dredgings, which occupied six weeks, were confined to the coasts of Guernsey and Jersey. Owing to the rocky nature of the sea-bed, and to the extraordinary rapidity of the tides, the work was very difficult and unsatisfactory; and one of my dredges was unavoidably lost, notwithstanding the rope was a new one and every precaution had been taken to prevent an accident of this kind. The depth of water seldom exceeded 30 fathoms; although there was one remarkable exception in a long submarine trough, called Hurd's Deep, lying about fifteen miles north of Guernsey, and having a depth of 60 fathoms and more.

As regards the Mollusca (to which I shall, as in former Reports, confine myself), they exhibit somewhat of a Mediterranean or South-European character. This will appear from the accompanying lists. No new species were procured; but scientific research does not consist entirely of such discoveries. It may be well questioned whether the reduction of some forms, which have heretofore been regarded as species, to the rank of varieties may not be of equal importance. The sexual relation of known species, their development, mode of growth, food, habits, economy, geographical and bathymetrical distribution, are all matters which require careful investigation. I had likewise an opportunity of observing for the first time the animals or soft parts of several species of shell-bearing Mollusca, and of rectifying the published descriptions of other species. In the first of these categories I would enumerate *Cardium papillosum*, *Rissoa crenulata*, *R. striatula*, *Defrancia Philberti*, and *Mangelia laevigata*. In the second category may be placed *Galeomma Turtoni*, *Chiton discrepans*, *C. cancellatus*, and *Trochus exasperatus*. Among the rarer or more local species taken by us were *Argiope capsula*, *Cardium papillosum*, *Tellina balaustina*, and *Crimora papillata*. It was also noteworthy that *Aplysia depilans* and *A. punctata* (usually considered distinct species) copulated when a pair was placed in a vessel of sea-water. This genus is not hermaphrodite in the same sense as *Helix*, inasmuch as each

individual of *Aplysia* performs the functions of one sex only, while each snail is at the time of sexual union both male and female.

The tide ebbs far on the coasts of the Channel Isles, especially during the equinoxes; at Guernsey the reflux extends about 30 feet, and at Jersey upwards of 40 feet. This is very different from what takes place in the Mediterranean, and it occasions a remarkable variation of habitat in many species. *Psammobia costulata* lives at Herm in the sand which is laid bare at low water, but in Shetland it occurs at a depth of between 80 and 90 fathoms. Hence we may infer that the depth of water cannot always be safely predicated from a cursory examination of shells either in a recent or fossil state. Their comparative solidity and size afford better criteria*.

A collection of the shells obtained on the present occasion has been placed in the British Museum.

We were indebted to Mr. Lukis, Mr. Gallienne, Mr. Macculloch, Mr. Le Lievre and Mr. Cooper, of Guernsey, and to Mr. Piquet and Mr. Rose of Jersey, for much assistance and pleasant companionship. From the first-named of these gentlemen I received *Purpura hamastoma*, from the second *Emarginula cancellata*, and from the third *Triton* (or *Murex*) *cutaceus*, all of which had been taken alive at Guernsey and Herm. There cannot be the slightest reason to doubt that *Triton nodiferus*, as well as *T. cutaceus*, inhabit this part of our seas. MM. Cailliaud and Taslé have recorded the latter species, and M. Cailliaud the former, as natives of the coast of Brittany.

Off Jersey were dredged a few worn specimens of *Cerithium vulgatum*, a species which does not seem to have been observed in a living state anywhere on the shores of the North Atlantic. It is common throughout the Mediterranean and Adriatic. M. Cailliaud has included it in his list of shells from the Loire-Inférieure, but only in a dead and rolled condition. From careful inquiries which I made at Jersey, I am enabled to state with some degree of certainty that no ballast containing shells has ever been brought there. I should be disposed to attribute the presence of *C. vulgatum* (as a semi-fossil shell) on the coasts of Jersey and Lower Brittany to an ancient submergence of the land, at a period probably anterior to that when submarine forests and peat-beds were formed on the shores of the north of Europe, and when the bays of St. Aubin and St. Michel were produced. Fossil shells, of Eocene species, were likewise met with; and they will be noticed in the Geological Section of this Meeting.

The following Tables may be useful to show which species are apparently restricted to the more southern limits of Great Britain.

I. Species found in the Channel Isles but not in Shetland:—

Argiope decollata.

— capsula.

Mytilus barbatus.

— Adriaticus.

Modiolaria costulata.

Crenella rhombea.

Arca lactea.

Galeomma Turtoni.

Lepton squamosum.

— sulcatulum.

Loripes lacteus.

Diplodonta rotundata.

Cardium aculeatum.

Cardium tuberculatum.

— papillosum.

Tapes aureus.

Gastrana fragilis.

Psammobia vespertina.

Donax vittatus.

— politus.

Amphidesma castaneum.

Macra glauca.

Lutraria oblonga.

Scrobicularia tenuis.

Solen vagina.

Mya Binghami.

* See 'British Conchology,' vol. iii. p. 27.

Gastrochaena dubia.
Pholas dactylus.
 — *candida.*
 — *parva.*
Teredo pedicellata.
Dentalium Tarentinum.
Chiton discrepans.
Emarginula rosea.
Fissurella Græca (probably).
Calyptræa Chinensis.
Haliotis tuberculata.
Cyclostrema Cutlerianum.
Trochus umbilicatus.
 — *lineatus.*
 — *striatus.*
 — *exasperatus.*
 — *granulatus.*
Phasianella pulla.
Rissoa calathus.
 — *costulata.*
 — *crenulata.*
 — *lactea.*
 — *pulcherrima.*
 — *striatula.*
Aclis supranitida.
 — *ascaris.*
Scalaria Turtoni.
Chemnitzia simillima.

Chemnitzia scalaris.
 — *fenestrata.*
 — *excavata.*
Odostomia dolioliformis.
 — *Warreni.*
 — *conspicua.*
 — *Lukisi.*
Barleeia rubra.
Ianthina Britannica.
Triforis pulchella.
 — *adversa.*
Nassa pygmæa.
Lachesis minima.
Murex corallinus.
Triton cutaceus.
 — *nodiferus.*
Trophon muricatus.
Defrancia Philberti.
Mangelia rufa.
Ovula patula.
Bulla cornea.
 — *hydatis.*
Aplysia punctata.
Pleurobranchus plumula.
Otina otis.
Melampus denticulatus.
Sepia elegans.

In all, 81 species of Testaceous Mollusca.

About the same number of species are found in Shetland but not in the Channel Isles. The greater part of the British Mollusca are common to both extremities. I estimate the total number to be 520. Of these may be reckoned 80 as peculiar to each extremity (and 80 more as inhabiting the intermediate area only); so that 360 is the probable number of species belonging to the Channel Isles and Shetland. The Mediterranean has from 700 to 800 species.

II. Species not observed north of the Channel Isles :—

Argiope decollata,
Lepton sulcatulum,
Cardium papillosum,
Teredo pedicellata,
Chiton discrepans (probably),
Emarginula cancellata?,
Rissoa pulcherrima,

Rissoa lactea,
Purpura hæmastoma?,
Murex corallinus,
Triton cutaceus,
 — *nodiferus,*
Bulla hydatis,
Sepia elegans,

being 14 species, of which 2 are doubtful as natives of the British seas.

Report on the Cultivation of Oysters by Natural and Artificial Methods. By FRANK BUCKLAND, M.A., M.R.C.S., &c.

FEELING highly honoured with the confidence you have placed in me to inquire into this subject—important not only in a physiological but also in a commercial bearing—I have since the last Meeting used my best endeavours to obtain all the facts and all the information circumstances and labour would allow—and this not only near at home, but also at distant localities. I would

beg to state that the facts hereafter mentioned are in no case derived from books, but from actual observation and experiment.

I have found that there is an amazing amount of most valuable information, because the result of practical experience, afloat. This information has, however, never yet been properly collected, sorted, and reduced to a scientific bearing. The further, moreover, that I investigate the question of that most mysterious mollusk the Oyster, the more I find that, after all, we know little or nothing at all about it.

The cultivation of the full-grown oyster is indeed pretty well known *after* it has arrived over the state of "brood;" but in its earliest stages of development comparatively little or nothing is known. It is the more important therefore to turn our attention in this direction, as legislation is actually at fault in the matter, and, as recent events have proved, those whose duties it is to make laws for the fisheries hardly know what laws to make.

I would propose to divide my Report under several heads—

1. The cultivation of the oyster by natural means.
2. The cultivation of the oyster by artificial means.
3. Experiments in hatching by artificial heat.
4. Experiments on a large scale on the fore shore.
5. The chemical analysis of the oyster.
6. On dredging.
7. Comparison of the French and English system of oyster-culture.
8. Experiments on oyster-spat.
9. On the cause of greenness in oysters.

Although we know not as yet the actual process by means of which the delicate and thin-shelled young spat manages to cling to various substances, yet we can by observation find out the objects which it seems to prefer; and these I would place in order as follows:—

1. The shell of the living oyster.
2. The shell of the dead oyster, technically called "Culch."
3. The shells of mussels, periwinkles, whelks, clams.
4. Pieces of crockery, glass, tiles, tobacco-pipes.
5. Iron.
6. Wood.

I would propose to examine these in rotation.

1. *The Shell of the Living Oyster*.—In the natural state, when not disturbed by the hand of man, we find that the tendency of the oyster is to accumulate in large groups, crowded and packed together in the most fantastic shapes. You find them of all ages, the nucleus of the group being a very old oyster, and around it oysters of ages varying from six or eight years to spat of as many months. It is curious to remark that these oysters have a tendency to accommodate each other; for I find that very seldom is there a dead one among the group, but that they are for the most part alive and thriving.

There is a locality in the North Sea, known to the deep-sea trawlers, not far from the island of Heligoland, in lat. 54° to 55°, long. 5° to 6°: the trawlers avoid this spot, because the great clumps of oysters cut their nets and do much damage. By the kindness of my friend Mr. Thomas, owner of the trawling-smack 'Hurricane,' I am enabled to show samples of these oysters; and I cannot but think that, were capital provided, and if experienced men undertook the task, the fishing of this oyster-bank, at the present high price of oysters, would turn out to be a remunerative speculation. The

oysters are exceedingly thin, but, as direct experiment proves, they are capable of being fattened if placed in a favourable locality.

2. *The Shells of the Dead Oyster, technically called "Culch."*—I look upon the study of the culch and its management as one of the most important things in oyster-culture; for upon its state, whether abundant or not abundant, whether clean or dirty, depends the detaining or the loss of the young oysters after they are emitted from the mother's shell, and also the important question as to whether the public grounds (or commons) should or should not be taken by private companies.

We start the question with two facts:—

1. That the oyster will adhere to dead oyster-shells in preference to any other substance, even the shells of the living oyster.

2. That in order that the spat may adhere, the culch must be perfectly clean and free from mud and weed.

There are but few localities where the shells of the dead oysters have accumulated in sufficient quantity to give the spat a chance of adhering; it is therefore necessary to collect these shells from elsewhere and throw them down upon localities where the spat is likely to fall. This process is carried out by oyster-culturists on a pretty large scale; and it seems almost providential that beds of oyster-shells should be found in the neighbourhood of the grounds which are cultivated. Thus, for instance, you will see on the map a place called the "Pan Sand," at the mouth of the Thames. Now, near this spot there is an accumulation of oyster-shells; and dredging-boats from various localities dredge up these shells and carry them on to places nearer inshore, and throw them again to the bottom of the sea, knowing full well that, if there be spat floating about, and if they be in a proper condition to adhere, these shells will assuredly catch it. How this Pan Sand oyster-bed came into existence I am quite unable to tell you; but, from the appearance of the oysters themselves, I can assert that the oysters were of great age, that they had lived there many years undisturbed by dredges, and that a considerable time has elapsed since they thrived in this locality.

Hence we learn an important fact, viz. that the spat seems to prefer adhering to a shell that is partially decayed, and softened, rather than to a new shell lately placed down. So great is the value of oyster-shells as "culch," that I have often cast a longing eye upon the shells which are carted away in large quantities from the oyster-shops in London and thrown on dust-heaps. They would be of much greater value if thrown on to the bottom of the sea, where they would certainly, if the season were favourable, form a trap for the floating spat. Such, however, is the abundance of old oyster-shells on the Pan Sand, that having, with the officers of the oyster-fishery with which I am connected, considered the idea, we find it would be cheaper to fetch them from the Pan Sand.

I cannot, however, quit the subject of oyster-shells without lamenting that no use has yet been found for them on land. They are now to landsmen but waste material; and I cannot help thinking that, if technology were to throw her lamp upon the matter, a use might be found for them. True it is that they make good lime; but lime can be obtained from other materials at a less expense. The fact, however, of the lime of the oyster-shell being so very good has led my friend Mr. Bartlett, Superintendent of the Zoological Gardens, to give them in a burnt state to poultry and the more valuable breeding pheasants. The birds seem to like it much, and it certainly is beneficial to laying hens and growing chicks. Another use of oyster-shells I have lately heard of. Mr. Browning, of Paglesham, tells me that the poor

people grind the shell and take as much of the powder as will cover a four-penny piece as a cure for ague.

3. We will now consider the third materials the spat loves to fasten itself to. The most prominent of these is "mussels." I am enabled to show you several fine specimens where oysters have adhered to mussels. The reason of this is obviously that the shell of the mussel presents the two requisites for the adhesion of the spat—perfect cleanliness and great smoothness. Oyster-proprietors should treasure this fact carefully in their memory, and should apply it. Mussels in beds form one of the greatest enemies to oysters, for they spin their web over them, accumulate mud, and suffocate the oysters beneath. They should therefore be dredged up, placed on the foreshore to die and decay, and the shells thrown back into the sea at the places where the spat is expected to fall.

For some reason or other the spat seems to like the shell of the common whelk, especially when the animal is dead. I now show you several specimens to prove this fact. Whelks, however, are far too valuable, not only as human food, but also as a bait for the cod in the North Sea cod-fishery, to which locality they are annually sent in quantities of such enormous money-value, to prevent our ever thinking of using whelk-shells as culch in large quantities.

The spat will also adhere to clams and to cockles. There is a large bed of these shells outside the mouth of the River Crouch in Essex; and friends of mine who have oyster-fisheries in this region dredge large quantities to place down on their grounds. I show you samples of all these facts.

4. We cannot be too observant of facts. I now show you a common saucer, on which oysters of three years old have fastened themselves. It was dredged up at a place called the Sandheads, at the mouth of the Thames; it is marked Queen's Channel in the maps. The French oyster-culturists have long been aware of the fact shown by the saucer, and in their oyster-parks place down all the broken potteryware they can find; and to these the oysters will adhere in considerable numbers—that is, in France. Unglazed earthenware has also attractions for the oyster; and upon this fact is founded the whole system of catching oysters by means of earthenware tiles, as I shall state hereafter.

5. It has often been a question as to whether oysters will or will not adhere to iron. I am able to answer this in the affirmative. The piles which support the pier at Herne Bay are covered over with broad-headed iron nails, and upon these, when the tides are very low, I have frequently found oysters adhering. A dredgerman, moreover, lately brought me in an exceedingly fine specimen, viz. the square bit of iron that was used formerly to go round the head of the wooden stock of an anchor; upon this square bit of iron I found no less than twenty-four oysters of various sizes and ages.

6. Oysters will also adhere to wood. Much has been said lately upon the advantage of placing down fascines or faggots for the use of the young oyster. I at once pronounce this to be a delusion and a snare, and I entreat those interested in the matter never to go to any trouble or expense in placing down fascines for this purpose. The experiment has been tried over and over again in England, and with the simple result that the fascines are excellent collectors of mud and seaweeds, sometimes of barnacles, but hardly ever of spat. I now show you two solitary specimens, one from the Isle of Ré, and the other from Mr. Wiseman's grounds at Paglesham; but the failures in this direction so much preponderate over the successes that I should never advise their use.

In the experiments now under my charge at Herne Bay, it is true, I have

used fascines very largely, and this for two reasons—first, to try the experiment of catching oysters with them; and secondly, to make the fascines do the very work they seemed most inclined to do, viz. to collect the weeds and the mud. I made with these fascines enclosures of various sizes and shapes, and inside them I placed the tiles, which were thus guarded both from the mud and also from the long belt-weed, which bothered me much by floating among the tiles and upsetting them. This is a good example of one of the difficulties of oyster-culture, and a proof that he who undertakes such matters must closely observe the actions of various materials when placed in the sea, and use these natural tendencies to the advancement of the object he has in view. I show a water-colour drawing of my works at Herne Bay.

On Dredging.

The subject of dredging has occupied my most serious attention. It is a question upon which legislation is at fault, or rather those who make the laws know not what laws they ought to make, as they have not studied the natural history of the animal which they wish to protect from injury.

Dredging consists in sailing over the grounds and scraping the ground with an instrument called a dredge; it is made chiefly of iron: the front part of it has a sharpish edge to pick up the oysters, which are received into a network, the network being of chain in the deep-sea dredging-boats, of cow's hide in those boats which fish in more shallow water.

As the dredge passes over the bottom of the sea it performs two operations:

1st. It picks up what oysters it may happen to meet with in its course.

2nd. It clears away the mud and dirt from the stones over which it passes.

The failure of spat has been popularly attributed to over dredging, *i. e.* the ground has been so much worked that all the oysters have been taken off from it, and none left for breeding-purposes. This theory I hold to be somewhat fallacious. True it is that the Jersey beds are now unproductive; but I fear that unless they are regularly dredged they will remain for ever unproductive. It is well known—and it is one of the first principles in oyster-culture—that in order to enable the spat to adhere the culch must be perfectly clean; if it is not dredged the mud will quickly accumulate on it, and there will be no places left fit for the reception of spat, should there happen to be spat.

It has been argued that if no parent oysters are left on the bed to spat there can be no young ones born to adhere to the culch. The answer to this is, that no number of dredges can pick up *all* the oysters on a given space of ground, and that there will be enough left to stock the ground should there be “a fall of spat,” in other words, should the spat live after it has been emitted from the mother's shell.

Supposing the ground to have but few oysters left on it on account of the place being so much worked with the dredge, the young oysters (should it be a favourable year for them) would find plenty of harbour on the clean culch, and the grounds would be restocked. Supposing, on the contrary, that the ground is thoroughly stocked with oysters, and has not been dredged for some time, they must all of them inevitably perish, on account of the culch being covered with mud, even though the year has been favourable for their living.

I would, however, draw a serious distinction as regards locality. In the case of the deep-sea oyster-beds, I should certainly not permit any dredging to go on during the months that the oysters are spatting, for the simple rea-

son that there is but very little mud and dirt about, and that therefore it cannot collect to a great extent upon the culch.

In the case, however, of oyster-beds, whether common or private, situated in rivers or near the mouths of rivers, I should advise the dredging to be continued with the greatest vigour up to the time that the first spat is seen on the culch, and then, and not till then, should the beds be allowed to remain quiet.

It has been proposed to stop the dredging during the months of May and June. What would be the inevitable consequence? It is during the months of May and June that the sea flora is most luxuriant; every stone and shell would become coated with weed and slime-like material of some kind or another, and this vegetable varnish upon it would entirely prevent the young oysters adhering to the culch, and they would inevitably perish. If, on the contrary, the dredges are kept well going during these two months, the culch will become thoroughly clean, and the spat will be able to adhere to the surface thus prepared for them.

The dredge in going over the ground would not, I feel convinced, do injury either to the spawning oyster or to the young spat. The former may be knocked about without any injury to its constitution, and the latter are so very minute that they would escape destruction by the dredge. Should, however, even the dredge destroy numbers of them, the mischief done would be well compensated by the space of ground cleaned and got ready for others; for it must be recollected that when the oysters on a well-stocked bed are at the height of spatting the water must be perfectly full of them.

Some friends of mine, whose living depends upon oysters, never think of taking off the dredges from their best spatting-ground until they see the spat fixed upon the culch. The theory that dredging during spatting-time injures the spat, they know perfectly well; they have therefore tried the experiment of leaving certain portions of the ground untouched; the consequence has been that less spat was found upon this ground than upon the neighbouring grounds where dredging was going on all the time; the grounds, in fact, which had been most dredged had most spat upon them. The case of the flats outside Whitstable is very remarkable. Large numbers of boats from Whitstable and other parts have for many years past been in the habit of dredging these flats every day in the year, and all the year round; it follows to reason that, unless it paid the men to go there, they would resort to other places. They, however, keep to the flats—a plain proof that oysters are there. They *are* there; and the reason is, that perpetual dredging has kept the ground clean, and that the spat floating about from the oysters on the neighbouring beds, these flats, and other places find a place suited for them, and adhere there. Could we look at the bottom of the sea at the mouth of the Thames, we should find a well-marked spot covered with oysters more or less, whereas all the ground surrounding it would be blank, containing no oysters at all. In illustration of this fact, I would imagine a large number of corn seeds thrown from the sky on to Salisbury Plain: should there happen to be a ploughed field in the plain, the seed would fall into the earth prepared for its reception, would germinate and grow; whereas if it fell on the ground not so prepared it must inevitably perish.

This question of dredging very seriously affects the taking in of common ground and applying it to private purposes. Two cases lately occurred—the one where Parliament granted the Herne Bay Company a considerable tract which had hitherto been common ground; the other case is that of the Roach River Fishery, where Parliament refused to give over the commons to a pri-

vate company. I premise by stating that commons are absolutely necessary for the stocking of private beds; they are generally in the neighbourhood of private beds, and the spat which falls upon them is the produce of the oysters upon the private bed. These commons are worked by poor men to obtain what they can upon them, and sell them to the owners of the beds; in so doing they keep the ground clean for the reception of spat.

In the case of the Roach River Fishery, the commons are situated in a comparatively narrow river, and the commons adjoin the private beds almost as near as the various paving stones in the streets. The spat, therefore, which are born on paving-stone A (which is private) are very likely to fall on the neighbouring paving-stone B (which is "commons"); anyhow the spat is carried up and down by the tide, and must of necessity fall in the river. The dredgers perpetually work these commons, and in so doing keep them ready for the reception of spat. When the spat falls, they pick it up in the form of brood, and sell it to the oyster-proprietors, from whose oysters it originally came. Now it would not be right that oysters belonging to Mr. A should become the property of Mr. B, because they happen to swim over an imaginary line and settle on the adjoining ground; it would be just the same thing as if, a farmer breeding a number of lambs in a private field, these lambs, because they happen to get over into a common where donkeys and geese are feeding, should become the property of the gipsies.

The case of the Herne Bay Fishery is different from that of the Roach River. Here, as will be seen from the map, the oysters may come from anywhere. The Whitstable people said they came from their ground; a few of them might possibly have done so, but experience shows that the set of the tides is towards the flats out to sea, and there oysters are always found. The authorities who laid down the Admiralty Charts gave their evidence before the House of Commons, that the set of the tide at Herne Bay was from east to west; in fact their evidence was hardly needed, as the drift of the shingle along the shores of Herne Bay amply proves it. Whitstable being to the westward of Herne Bay, the prevailing set of the tide would carry the spat back to their ground, and not on to that of the Herne Bay ground. There was not very long ago a large number of spat picked up on the Herne Bay ground, and I learnt from observant persons living at Herne Bay that at that time the wind was from the eastward.

Periwinkles.—To those who lay oysters on the foreshore I would now venture to give a valuable hint, which they may possibly know before. Between high- and low-water mark green weed is very apt to accumulate; this collects mud, and in other respects does injury to the oysters. No amount of dredging or other cleaning will keep this green weed off; it is nevertheless very desirable to get rid of it; and this would form an excellent problem for those who are in the habit of studying what is called the police of nature—that is, to mark the way in which the undue increase of one animal is kept down by the increase of another. Everybody knows that periwinkles are of great use in keeping clean the walls of an aquarium. My friends Mr. Wiseman and Mr. Browning of Paglesham, who are proprietors of large oyster-fisheries, have applied the observed fact of periwinkles eating weeds to a practical operation on a large scale.

The foreshore where their oysters are laid is very subject to this green weed; they have therefore turned out large numbers of periwinkles upon it, and these, eating up the green weed, clean the foreshore in the most wonderful way. It is curious to remark how periwinkles, obeying their apparently natural instinct, are in the habit of climbing up poles which are put in as

beacons; they crawl up these poles as far as they can, and then, remaining out of water till they are nearly dried up, drop back again.

Experiments on the Foreshore on a large scale.

The Herne Bay Oyster Company having deputed me to carry out experiments on their grounds at Herne Bay according to the much talked-of French system of oyster-culture, I have since the month of May last been almost exclusively occupied in these experiments. Having carefully studied the whole system of tiles and fascines as adopted in the Isle of Ré, actual experience has shown me that the French system cannot be adopted on the English foreshores in exactly the same manner as it has been in France; almost at every point minor puzzles occur, which require much foresight and perpetual contriving to overcome. The Kemmerer tiles are, as is well known, coated with cement on the under side, so that, the oyster having fixed itself, the cement can be broken in pieces, and the oyster, when arrived at the age of one year, immediately let free. I have not adopted this system, principally on account of the expense it would necessarily entail. I have, however, with the assistance of an ingenious brick-maker, contrived a tile of such a size and such a consistency, that the necessity of having cement is avoided, and the oyster will be able to be set free without fracturing its shell.

At a comparatively small cost, but with great personal labour, I have laid down *four thousand* of these tiles on the foreshore at Herne Bay. Three great difficulties have occurred: these are, firstly, to keep the tiles from being knocked over by the waves; secondly, to obviate their unaccountable desire to sink into the mud, and in consequence become useless; and thirdly, the inconvenience of the very short time allowed by the tides to place the tiles in their proper position on the foreshore. Most of these matters I have, however, seriously considered, and, with the able help of Mr. Dilnot, a tradesman of Herne Bay, have overcome.

The tiles I placed down at three different periods in the year, viz. in June, July, and beginning of August; I examined them carefully every spring tide: the waves have displaced them but very slightly, and broken hardly any.

It is as yet (September) rather early to report the actual result of the operation, as the spat would not yet be sufficiently large to be easily appreciable; I therefore hope that the present warm weather may encourage what is called the Michaelmas spat, and that the tiles may be found to have caught some.

In their present condition the tiles are covered with what are locally called "Nuns," in other words balani or acorn-shells; but no young oysters are to be seen as yet.

In accordance with the French plan, I have placed in my submarine parks and gardens broken pieces of glass, earthenware, pottery, &c. In France these objects would have become covered with oysters. At the locality, however, where we placed them the nuns took the place of the oysters. The numbers of numerous marine creatures which have adhered to the tiles amply prove that their structure is most favourable for the catching of spat, should there be any to catch; and the local fishermen, who first laughed at my operations, no longer laugh, but express their opinion that the tiles would be capital things, *should there be any spat about*.

Anxious to ascertain the fact whether the tiles did not catch spat because they were not in structure adapted so to do, or because the spat perished between the time of its being emitted from the mother's shell and in fixing itself, I devised the following experiments:—I procured large glass jars and bottles, and, placing in these oysters which I could see to be in a spatting

condition, covered over the top with a material which would admit the water freely into the bottle, and placed it at the bottom of the sea; defended from injury by fascines. Upon subsequent examination I found that the young oysters had *not* adhered to the sides of the glass, though, in my opinion, there was no reason why they should not do so, except the temperature of the water surrounding the bottle. Experiment No. 2.—I obtained wooden boxes, and, without injuring them, placed in each one or two spatting oysters; I placed tiles over these oysters, and over the tiles a covering of coarse canvas, the meshes of the canvas being large enough to let in water, but not let out the oyster-spat. My idea in doing this was to prove whether, or not, as has been supposed by some, the spat immediately on being emitted from the parent fixes itself. These boxes were placed on the foreshore in such a locality that they would never be dry; after they had been down one month I cut off the canvas and examined the tiles, but not one single trace of oyster-spat could be seen, the oysters which had been shut up in the box underneath the tiles I found to be quite hearty, and to have got very fat on their captivity. I tried the same idea in closing the spatting oyster between two flower-pots wired together; here again the results were *nil*. To my mind these experiments prove conclusively that the young ones cannot survive the state of things favourable to their parent, and that they certainly do *not* adhere the moment they are sent forth from their mother's shell.

Comparison of the French and English System of Oyster-culture.

I have now examined both methods very carefully, and have come to the conclusion (and I am bound in honesty to state it) that in my humble opinion the French system has been much overrated; or at least the idea that the system is applicable to this country is more or less fallacious.

The public seem to have got it into their heads that our English system is faulty, because for several successive years it failed to produce any large number of oysters; at the same time highly favourable reports were issued of the success of cultivating oysters in France by what is called the artificial system. I candidly confess I was one of the first to fall into the trap, and to imagine with others that, *because* the tiles, fascines, &c. were placed in the sea, therefore the oysters could be made to breed, and that if you placed tiles you would have oysters, if you placed no tiles you would have no oysters.

As I have explained before, the English system is to catch the spat upon culch, the French to catch it upon tiles. I have examined both systems, and come to the conclusion that the tiles will (except under certain favourable circumstances) never beat the culch.

I have been to the Isle of Ré, and have seen (through the great kindness of Dr. Kemmerer) the whole system; and the long and short of it is this:—For many years the oyster-spat in France was totally neglected, and the inhabitants thought nothing about turning their beds to profitable account. The learned pisciculturist, M. Coste, suggested the idea of tiles being placed down, the idea having, I believe, been first suggested by a poor mason, M. Bœuf, with whom I have had a long conversation. The tiles, fascines, &c. were placed down under the patronage of the government, and they were picked up covered with young oysters. The success was pronounced complete, fascines and tiles were all the rage, and all those who had oyster-fisheries thought their fortunes were made.

The fact of the matter is, that the first year these various oyster-catching implements were laid down happened to be a year famous for an exceedingly heavy fall of spat; in other words, a vast majority of the young spat

born lived, thrived, and ultimately adhered to whatever they could find to adhere to. They found the fascines and tiles, and covered them as bees cover the boughs of a tree at swarming-time; and the idea was at once started that these fascines and tiles were the means, as it were, of creating the oysters which otherwise would not have been created.

The first two or three years after these tiles, &c., were laid down happened to be good years for the spat living; but for the last few years the spat has not lived, and the natural consequence has been that they have not been found on the tiles in very large quantities. Oysters, in fact, are just as scarce this year in France as they are in England. If the artificial system with tiles had been such a great success, and had the tiles caught the spat when culch would not catch the spat, it would of necessity follow that oysters in France would have been very cheap, whereas in fact they are quite as dear as in England, and there are so few of them to be had that French agents are at this moment in this country buying all they can get hold of.

There can, however, be no doubt whatever that as a rule the oysters spat much more freely on the west coast of France than they do at the mouth of the Thames and the adjoining coasts of Essex. The reason of this is, to my mind, obvious. Oysters require heat, or rather warmth, in their younger state. From the nature of the vegetation the general state of the climate can be pretty well ascertained. Now at the headquarters of artificial breeding, at the Isle of Ré, the temperature is so great that vines grow luxuriantly. In England the temperature is such that we can only grow corn, turnips, &c.

The latitude of the Isle of Ré, which is situated in the Bay of Biscay, is about 46° , whereas the mouth of the Thames is about $51\frac{1}{2}^{\circ}$; it is natural therefore to suppose (as indeed the facts show) that in ordinary years there should be a much larger fall of spat at the Isle of Ré than on the east coast of England. The state of things on the west coast of Ireland seems to confirm this conclusion; for here, again, the oysters breed much more freely than they do in England, the cause being the warm moist climate and the even temperature of the air.

In accordance with hydrographical facts, the oysters bred both in Ireland and Ré are taken elsewhere to fatten; those from Ireland are brought round by vessels or else in boxes by railway and laid down at the mouth of the Thames, where in a year or so they increase greatly in the quantity of meat contained in the shells. The shell, too, seems inclined to take on the characteristics of the oysters natural to the place, though direct observation will not as yet enable me to be sure about the fact "whether the young of transported oysters will, if born in the locality where a purer breed of oysters exist, assume the character of the natives of the place:" this is a subject of the highest importance, about which no facts are yet known. In Ré the lean oysters are placed in what are called clares—that is to say, mud ponds; in these mud ponds they find food, and certainly become fatter than at the place where they were first born.

Chemical Analysis.

The object of this investigation is, first, to ascertain whence the oyster obtains the mineral material to secrete his house, and, secondly, what those materials are; for, commercially speaking, the proportion of the meat to the shell is of the greatest importance to the merchant who has to pay high prices for the transport of oysters long distances. If he buys oysters with a thick shell, containing a large proportion of mineral, he cannot possibly obtain as much profit as if there were more meat than shell at a given weight.

With this idea, I have, with the assistance of my clerk, ascertained the proportion of meat to shell in nearly forty kinds of oysters. I am indebted to Mr. Moore, of the Derby Museum, Liverpool, for many specimens of these oysters; and I shall be exceedingly obliged to any gentleman who will give me any specimens to enlarge my table.

*Proportion of Meat to Shell in different kinds of Oysters, ascertained by
Mr. Frank Buckland.*

Colchester	}	One-fourth.
Whitstable		
Paglesham	}	One-fifth.
Herne Bay		
Falmouths	}	One-sixth.
Callies		
Mayor's Bank, Galway	}	One-seventh.
Plymouth		
Tramore Bay, Ireland	}	One-eighth.
Eastbourne, Sussex		
Milford, Wales	}	One-ninth.
Isle of Skye		
Red Bank Burrin, Collare, Ireland	}	One-tenth.
Sandheads, Mouth of Thames		
Sir W. Wallace's, Loch Ryan, Scotland	}	One-eleventh.
Exmouth Harbour		
Wexford, Ireland	}	One-twelfth.
Clew Bay, Ireland		
Skibbereen, Cape Clear	}	One-fifteenth.
Penmaenmawr, Wales		
Auglimish Bay, Ireland	}	One-twentieth.
Boston, Lincolnshire		
Ross Muck, co. Clare, Ireland	}	
Waterford, Ireland		
Channel between Dover and France	}	
Hayling Island, near Portsmouth		
Beaumaris, Wales	}	
Shetland		
Howth Bank, Ireland	}	
Mouth of the Humber		
North Sea	}	
Isle of Ré, France		

It struck me that, whereas the oysters were very different in appearance, their mineral ingredients would differ correspondingly. I have therefore obtained the assistance of Mr. A. P. Tarnier, F.C.S. He finds that the chemical ingredients composing the oyster-shell are three—animal matter, phosphate of lime, and carbonate of lime.

Six different kinds of oysters were taken from localities widely apart; and the result (given in the Table) proved directly that, as I had supposed from theory, the more animal matter there was in an oyster-shell, and the less mineral, the greater value it would be for the market; it is very satisfactory to find that the chemical ingredients of the shell of the oyster tally almost exactly with the prices they bear at the market. I have not as yet had time to examine the meat of the oyster, but propose to report on this at a future time.

Animal matter.		Phosphate of lime.		Carbonate of lime.	
Herne Bay Native...	·096	Rivedoux Rocks ...	·075	North Sea	·948
Rivedoux Rocks ...	·087	Herne Bay Native...	·047	Red Bank Burrin ...	·943
Paglesham	·075	Colchester	·028	Colchester	·910
Colchester	·062	Paglesham	·020	Paglesham	·905
North Sea	·041	Red Bank Burrin ...	·020	Herne Bay Native...	·857
Red Bank Burrin ...	·037	North Sea	·011	Rivedoux Rocks ...	·838

Experiments on the Hatching of Oyster-spat.

It is my firm conviction that one of the chief reasons why the young spat have died in such countless numbers in the open sea is, that the water is not of a sufficient temperature to allow them to live and thrive during the period in which the process of adhesion takes place. Sudden alterations of temperature, especially from warm to cold, are also particularly fatal in their results. I have therefore instituted a series of experiments to endeavour, if possible, to give the young spat a continuous supply of water at a constant and unvarying temperature. In doing this I have gone to some considerable expense; but, as a set-off against this, I have been greatly aided by Mr. Dilnot, a tradesman of Herne Bay, who has most kindly placed his premises at my disposal.

By a somewhat complicated bit of machinery we have been enabled to keep up a constant supply of sea-water continually flowing for several weeks, the temperature being arranged by an application of artificial heat. Upon examining the stones, shells, and other materials in this artificially warmed water we were much pleased to find the shells adhering in the position usually chosen by the young oyster itself, viz. the underside of the shell. The adhesion was pretty firm, but as the water dried the shell became loose, and ultimately fell off. I cannot, however, but look at this as a partial approach to success. It appears to me that the young creatures had taken up the position they intended to occupy, and that they died from some other causes. What those causes were I am hardly at present able to state; but I am quite certain and positive that I know what *two* of them were, and trust to be able to meet the difficulties in future trials. The task of applying heat artificially is no easy one, and presents many mechanical difficulties, which at present I can hardly see how to meet. I do not, however, despair, and propose further experiments during the next season. I mentioned this idea at the last Meeting of the Association, at Bath, and have since endeavoured to carry it out. Experiments of a similar kind have, I have heard, been instituted by Mr. William Crofts; but I have not seen his apparatus. Experiment has shown me the exact temperature the spat like best.

The Question of Green Oysters.

This is, both commercially and socially speaking, a most important question. The River Roach, situated on the coast of Essex, has for a hundred years or more produced large quantities of oysters; but, strange to say, *none* of these oysters are ever sent to the English market, being all, without exception, sent to the markets at Dunkirk and Ostend, and thence to Paris, Berlin, and even, I believe, as far as St. Petersburg. The reason why they are not sent to the English market is simply that they are green in appearance. I have examined into this question with very great care, and in doing so have been greatly assisted by my friend Mr. W. Wiseman, of Paglesham. The oysters, strange to say, are only green in the winter, and

not in the summer. The greenness does not extend throughout the whole of their body, but simply to their beard or fin. The cause is totally unknown: some attribute it to the green weed among which the oysters are placed; others to the infusoria upon which they feed: for all practical purposes suffice it to say, they are most excellent and nutritious food to the human frame. Dr. Letheby has made an analysis of them for Mr. Wiseman, and reports that they are perfectly wholesome and contain no copper. Practical experience, moreover, proves that they are wholesome, and many dozens of them may be eaten with impunity. The oysters at Marennes, in France, are so highly esteemed by the French people on account of their greenness, that the oyster-culturists at Marennes placed them in pits in order that they might become green. From all that I can observe or ascertain, my present opinion is (and is further confirmed by experiments which I have carried out), that the cause of the greenness is the presence of chlorophyll in the beard of the oyster. From this fact we may deduce an important practical conclusion, viz. that, if it be desirable to get off the greenness from the oysters, all that is required will be to place them in pits, and place a covering of hurdles, brands, or other materials over them, so as to prevent the action of light, the chlorophyll will, I believe, not be formed, and the oyster in consequence not be able to take it up. This is a practical suggestion which I have made to Mr. Wiseman, and which he has promised at once to experiment on.

Falmouth Green Oysters.

The green oysters from Falmouth have undoubtedly a bad reputation, on account of their being said to contain copper. Mr. Fox, of Falmouth, has been good enough to send me samples of these oysters. I have submitted them to the analysis of Mr. Turner, who reports the presence of copper in them, but in very minute quantities, hardly sufficient, I should imagine, to do injury to the human system; still that it is present there can be no doubt. It may be that the oysters obtain the copper from a solution in sea-water, or from the fresh water running from the copper-mines. I propose, if opportunity serves, to visit Falmouth, and inquire more minutely into this fact. Falmouth oysters are imported in considerable quantities to the mouth of the Thames; and practical experience shows that they lose all their green colour on being exposed for a few months in water suited to their fattening. The bodies of these Falmouth oysters when first caught are almost as green as arsenical paper; the shells also look green in external appearance. Upon placing them in spirits of wine the spirits become dark green; there can be no doubt whatever that this is caused by the presence of chlorophyll.

In conclusion, I would remark that so anxious am I about the cultivation of the waters, especially with reference to the Salmon and the Oyster, that I have established, at my own expense, at the Royal Horticultural Gardens, under the Science and Art Department of the South Kensington Museum, a "Museum of Economic Fish-culture," in which I have exhibited drawings and preparations illustrating the habits and natural history of the salmon, together with samples of oysters from many parts of the United Kingdom. The development of the young oyster from its embryonic state to the time that it is fit for market, together with the various modes of its cultivation, both by ordinary and by artificial methods, is fully illustrated. Samples of oysters, alive or dead, from any part of the world will be most thankfully received; for any fact, however insignificant it may seem to be, is valuable.

First Report of the Committee for exploring Kent's Cavern, Devonshire. The Committee consisting of Sir CHARLES LYELL, Bart., Professor PHILLIPS, Sir JOHN LUBBOCK, Bart., Mr. JOHN EVANS, Mr. EDWARD VIVIAN, and Mr. WILLIAM PENGELLY (Reporter).

THE celebrated Kent's Cavern, or Kent's Hole, is about a mile due east from Torquay harbour. It is situated in a small, wooded, limestone hill on the western side of a valley which, about half a mile to the south, terminates on the northern shore of Torbay.

The hills which surround the district consist of limestone, greenstone, clay-slate, and a reddish grit or compact sandstone. The two last are traversed by veins of quartz; and, with the possible exception of the greenstone, they all belong to the Devonian system. Indeed the entire Torquay peninsula is exclusively made up of rocks of this age.

According to tradition, there were formerly four or five entrances to the cavern, of which two only were generally known, the others being merely narrow apertures or slits through which, until they were blocked up from within, the initiated were wont to enter clandestinely. The remaining two are about 50 feet apart, and occur in the face of one and the same low natural cliff, running nearly north and south, on the south-eastern side of the hill. The northern entrance is in form a rude triangle, about 6 feet high and 8 feet wide at the base. The southern is a natural and tolerably symmetrical arch, $9\frac{1}{2}$ feet wide at the base, and 6 feet high. Its form is due partly to a gentle curvature of the strata—the apex of the opening being in the anticlinal axis—and partly to the actual removal, by natural causes, of portions of the limestone beds; the base of the opening, or chord of the arc, consists of undisturbed limestone; so that the entrance may be aptly compared to the mouth of an oven.

From the time of the researches and discoveries which, forty years ago, rendered the cavern famous, to the commencement of the exploration under the auspices of this Association, the southern entrance has been blocked up, the northern alone being used by visitors. The base of the latter is about 189 feet above the level of mean tide*, whilst that of the former is about 4 feet lower.

The Cavern has been known from time immemorial. Even tradition fails to reach back to the date of its discovery. It did not, however, attract the attention of scientific inquirers until September 1824, when Mr. Northmore visited it with the double object, as he stated, “of discovering organic remains, and of ascertaining the existence of a temple of Mithras,” and he declared himself “happy to say that he was successful in both objects.” He was speedily followed by Mr. W. C. Trevilyan, who, according to the Rev. Mr. M'Eney, “was the first that obtained any results of value to science.” Mr. M'Eney, whose name must be for ever associated with the cavern, first visited it in the summer of 1825. He was at that time quite inexperienced in cavern researches; for he states that the party which he had been induced to accompany was a large one, and that on entering the cavern he “was the last of the train, for he could not divest himself of certain undefinable sensations, it being his first visit to a scene of this nature.” The visit was a memorable one; for, separating himself from his companions, and devoting himself to

* A “bench mark” of the Ordnance Survey in the road from Torquay to Ilsham farm, and which is at no great distance from the cavern, is, as Col. Sir H. James kindly informs me, 131·629 feet above the level of mean tide at Liverpool. By pocket aneroid, the base of the northern entrance of the cavern is 57·5 feet above this mark.—W. P.

what he conjectured to be a favourable spot, he found several teeth and bones. He thus describes his feelings on the occasion:—"They were the first fossil teeth I had ever seen, and as I laid my hand on these relics of extinct races, and witnesses of an order of things which passed away with them, I shrank back involuntarily; though not insensible to the excitement attending new discoveries, I am not ashamed to own, that in the presence of these remains I felt more of awe than joy." He at once communicated his discovery to Dr. Buckland, and with great energy followed up his "good fortune" for several years. So far as can be ascertained from his memoranda, the date of his latest visit was August 14th, 1829.

Though he at one time intended to publish a narrative of his labours and discoveries, and had made arrangements for the requisite illustrations, the intention was unfortunately abandoned. After his decease, it was feared that his manuscripts had been destroyed or lost; but after experiencing a variety of fortune they passed into the hands of Mr. Vivian of Torquay, who from them compiled a Memoir which was published in 1859*.

In 1840, Mr. Godwin-Austen read a paper before the Geological Society of London, on the "Bone Caves of Devonshire," when he described the results of his investigations in Kent's Hole.

In 1846, the Torquay Natural History Society appointed a Committee to conduct an exploration of a small portion of the cavern. Though their object was mainly to obtain specimens for the Society's Museum, very careful attention was given to the positions and associations of all the articles found. A paper embodying the results of this investigation was drawn up by Mr. Vivian, a member of the Committee, and read in 1847 before the Geological Society of London. A mention of this communication appeared in the 3rd volume of the Quarterly Journal of the Society.

Though it may be doubted, perhaps, whether any of the foregoing explorations were conducted with that rigid observance of method which is now held to be necessary, all the explorers are unanimous in stating that they found flint "implements" mixed up with the remains of extinct animals.

In 1858, the results of the systematic and careful exploration of Brixham Cavern, on the opposite shore of Torbay, induced the scientific world to suspect that the alleged discoveries which, from time to time during a quarter of a century, had been reported from Kent's Hole, might, after all, be entitled to a place amongst the verities of science; and from that time various proposals for further investigations have been made. As is well known, these suggestions took a definite form at the last Meeting of this Association, when a liberal grant of money was made, and a Committee was appointed for the purpose of further exploration. It is the object of this communication to state what up to this time the results have been, so far as they are at present determined.

The Committee have great pleasure in stating that, in reply to their application for permission to make the proposed investigation, the proprietor, Sir L. Palk, Bart., M.P., assured them most promptly that it would "give him great pleasure to place every facility in their hands." He placed the cavern in their exclusive custody, and suggested the most satisfactory arrangement for the ultimate disposal of such objects of interest as might be found.

Though large portions of the deposits were broken up by Mr. M'Enery and his successors, there is still within the cavern a very considerable amount of virgin ground. The Committee, however, were desirous of selecting an area in which not only were the deposits certainly intact, but which would

* Cavern Researches. Simpkin, Marshall and Co., 1859.

not present any very great difficulties in working. After a visit of inspection it was decided to undertake the exploration of the large chamber into which the southern entrance immediately opens. The mode of investigation was laid down, trustworthy and intelligent workmen were engaged (Mr. Charles Keeping, brother of the well-known fossil collector, being the chief), and the work, consigned to the superintendence of the two resident members of the Committee, Mr. Vivian and the Honorary Secretary, was commenced on March 28th of the present year.

Immediately outside the cave lay a considerable talus of earth and stones, the upper portion of which, at least, is believed to have been thrown out by Mr. M'Enery, who conducted his researches through the northern opening. It was necessary to cut through this mass in order to reach and make available the entrance which the Committee had selected for their operations. This material was very carefully examined, partly for the purpose of detecting any objects of interest which it might contain, and partly as an initiatory exercise for the workmen.

The cavern is in no part subject to any considerable amount of drip; and no portion of it is drier than the chamber selected for exploration. Since the commencement of the work unusually heavy rains have fallen in the district, but water has entered through the roof at a very few points only, and in no instance in such an amount as to produce discomfort or inconvenience.

The following is the succession of deposits, in descending order, which the chamber contained.

1st. Huge blocks of limestone which had manifestly fallen from the roof. Many of them required blasting to effect their removal; and in several instances it was necessary to blast even the masses into which they were by this means divided. One of the blocks measured 11 feet long, $5\frac{1}{2}$ half broad, and $2\frac{1}{2}$ thick; hence it contained upwards of 100 cubic feet, and must have weighed fully 7 tons. In some cases two or three of them lay one on another, and, in a few instances, were firmly cemented together by a separate cake of stalagmite between each pair; whilst others lay unconformably with considerable interspaces. Occasionally, what appeared to be a boss or dome of stalagmite proved to be a block, or two or three small blocks, of limestone invested on all sides with a stalagmitic sheet. Certain masses, lying at some distance from a drop, were without even a trace of stalagmite.

2nd. Beneath these limestone blocks there was a layer of mould of an almost black colour. It varied from a few inches to upwards of a foot in depth.

3rd. Underneath the black soil came a cake of stalagmitic breccia, made up of comparatively small fragments of limestone so very firmly cemented together with carbonate of lime as occasionally to require blasting. It was rarely less, but not unfrequently much more, than a foot thick. Everywhere it was firmly attached to the walls, and it occasionally extended completely across the chamber. Not unfrequently, however, the centre of the chamber was altogether destitute of this breccia, in some instances, because there is no drip near the area, in others, because it was intercepted by an overlying limestone block.

4th. The breccia is succeeded by the ordinary reddish cave-loam, which contains a large number of limestone fragments, varying in dimensions from bits not larger than sixpences, to masses but little smaller than those which lay on the surface. They lie at all angles without anything like symmetrical arrangement. In fact the entire deposit is without any approach to stratification. Many of the stones are partially encrusted with calcareous matter,

and not unfrequently loam, stones, and splinters of bones are cemented by the same substance into a very tough breccia. The presence of a calcareous drip is more or less traceable everywhere. Hitherto the cave-earth has been excavated to the depth of 4 feet only. How far it extends below this, or what may be beneath it, is at present unknown. Where it is not covered with the stalagmitic breccia, the black soil lies immediately on it; but the line of junction is everywhere sharply defined. In no instance do the two commingle.

Since the large masses of limestone occur at all levels in the cave-earth as well as everywhere above it, it is obvious that whatever may be the cause to which their fall is attributable, they cannot be referred to any one and the same period. They fell from time to time throughout the accumulation of the cave-earth, they continued to fall whilst the stalagmitic breccia was in process of formation, as well as during the introduction of the black mould, and they are amongst the most recent phenomena which the cavern presents. And even of those which lie on the surface, there is conclusive evidence that in some cases a considerable interval of time must have elapsed between the fall of two blocks lying one on the other—an interval sufficiently great for the formation of the cake of stalagmite between them, and which is sometimes fully 6 inches thick. There can be little doubt that some of them fell very recently, even when measured by human standards.

It is by no means easy to determine the cause which threw them down. To call in the aid of convulsion seems undesirable, since it would be necessary to do so very frequently. Moreover, it may be doubted whether anything short of a violent earthquake would be equal to the effect. Though the roof of the chamber is of very great span and entirely unsupported, and though it presents appearances which are not calculated to inspire confidence, the violent concussions produced by the frequent blastings already mentioned, blastings which not unfrequently throw masses of limestone, weighing upwards of a ton, to a distance of several feet, have never brought down even a splinter.

The fall of the blocks has sometimes been attributed to changes of dimensions in the roof arising from changes of temperature; but the fact that the cavern temperature is all but constant throughout the year, seems fatal to this hypothesis.

The masses lying on the surface were a sufficient guarantee that the deposits beneath them remained intact. There can be no doubt that they are at once a proof and the cause of the undisturbed character of the soil they cover. A portion of the cavern so easily accessible as is this chamber, would not have been spared by Mr. M'Enery, but on account of some great difficulty or discouragement; and in fact he states that the fallen masses completely foiled him in his attempts to make explorations in it, excepting in one branch some distance south of the area selected by the Committee. Their own characters, moreover, render it absolutely certain that the deposits have never been violated.

The following is the method of exploration which has been observed from the commencement, and which it is believed affords a simple and correct method of determining the exact position of every object which has been found.

1st. The black soil accessible between the masses of limestone on the surface was carefully examined and removed.

2nd. The limestone blocks occupying the surface of the deposits were blasted and otherwise broken up, and taken out of the cavern.

3rd. A line, termed the "datum line," is stretched horizontally from a fixed point at the entrance to another at the back of the chamber.

4th. Lines, one foot apart, are drawn at right angles to the datum line, and therefore parallel to one another, across the chamber so as to divide the surface of the deposit into belts termed "parallels."

5th. In each parallel the black mould which the limestone masses had covered is first examined and removed, and then the stalagmitic breccia, so as to lay bare the surface of the cave-earth.

6th. Horizontal lines, a foot apart, are then drawn from side to side across the vertical face of the section so as to divide the parallel into four layers or "levels," each a foot deep.

Finally, each level is divided into lengths, called "yards," each 3 feet long, and measured right and left from the datum line as an axis of abscissæ.

In fine, the cave-earth is excavated in vertical slices or parallels 4 feet high, 1 foot thick, and as long as the chamber is broad where this breadth does not exceed 30 feet. Each parallel is taken out in levels 1 foot high, and each level in horizontal prisms 3 feet long and a foot square in the section, so that each contains three cubic feet of material.

This material, after being carefully examined *in situ* by candlelight, is taken to the doorway and reexamined by daylight, after which it is at once removed without the cavern. A box is appropriated to each yard exclusively, and in it are placed all the objects of interest which the prism yields. The boxes, each having a label containing the data necessary for defining the situation of its contents, are daily sent to the Honorary Secretary of the Committee, by whom the specimens are at once cleaned and packed in fresh boxes. The labels are numbered and packed with the specimens to which they respectively belong, and a record of the day's work is entered in a diary.

The same method is followed in the examination of the black mould, and also of the stalagmitic breccia, with the single exception that in these cases the parallels are not divided into levels and yards.

With very rare exceptions the cavern has been visited daily by one, and frequently by both of the Superintendents; and Monthly Reports of progress have been regularly forwarded to Sir Charles Lyell, the Chairman of the Committee.

Though it would be premature to attempt anything like an exhaustive list, it may be of interest to furnish a brief and general account of the objects which have been found.

Of the articles met with in the black mould, those occurring *between* the fallen masses of limestone have been kept distinct from such as have been detected *beneath* them. Such a division, however, is not rendered necessary by the characters of the objects themselves, and will not be attended to on the present occasion. In this category also may be placed the greater number of the specimens found in the talus outside the cavern. The collection is of a various miscellaneous nature. It consists of stones of various kinds, human industrial remains, charred wood, bones of various animals, marine and land-shells, and the broken shells of hazel-nuts. It passes from the Rabbit's nest lined with clean dry fur and containing a couple of fresh green ivy-leaves, and numberless fragments of wine and porter bottles flung away by parties who have visited the cavern mainly from a love of frolic, back to the age of bronze implements and of flint flakes, and probably represents from fifteen hundred to two thousand years.

The stones are in most cases well rounded, and, at least, some of them are

of marine origin, since they are distinctly lithodomized. They consist of limestone, quartz, red grit, greenstone, and flint; all except the last derivable from the rocks of the immediate district, and were probably obtained from the neighbouring beaches, where also the flints were perhaps found; for though there is no flint *in situ* within five miles; it is a well-known fact that such pebbles are met with on existing beaches at much greater distances from any known accumulation of flints in place. The rounded stones are extremely numerous in the black mould, and were undoubtedly selected and taken to the cavern; but for what purpose it may not be easy to determine. There are also several pieces of hard greenish-grey grit of an elongated form, which were perhaps used as whetstones. Angular pieces of slate are also numerous. They are probably fragments of articles fashioned by man, as occasionally a piece is met with which is obviously a portion of a curvilinear plate. Such plates are mentioned by Mr. M'Enery, who supposes them to have been used as covers for earthenware vessels. The human industrial remains consist of articles in bronze and in bone, pottery, spindle-whorls, and flint-flakes. The bronze articles are a fibula, the bowl and part of the stem of a spoon, a spear head, a fragment of a socketed celt, two or three rings, one coil of a helical spring, a pin about $3\frac{3}{4}$ inches long, and an object resembling a horseshoe in form, but not more than an inch long. In this connexion may be mentioned a lump of metal which, from its general appearance, would be termed copper ore, but from its interior, a small portion of which has been exposed accidentally, it is probably native copper, or a mass of metal which has been smelted. A similar mass mentioned by Mr. M'Enery, is said to have been analyzed "by Mr. Phillips and found to be pure virgin ore." Much of the pottery, excepting one small piece, undoubtedly Samian, is extremely coarse, and in most cases it is unglazed. A large number of fragments have been found, but nothing approaching a perfect vessel. They are generally ornamented, and from the different patterns, as well as from other facts, it may be concluded that they represent a considerable number of utensils. One piece probably formed part of a vessel in which things were burnt, as on its inner surface there is a firm admixture of clay and small bits of charcoal. Much of the pottery is without doubt of Roman age.

The objects fashioned in bone are a comb, which in size and outline resembles a common shoe-lifter having teeth cut in the broad end; a spoon, neatly formed of a portion of a rib, and measuring about 6 inches long and $\frac{9}{10}$ ths of an inch broad; a chisel about $2\frac{6}{10}$ ths inches in length, and at its broad end $\frac{4}{10}$ ths of an inch in width; a wedge, somewhat rudely fashioned out of a horn or antler; two small fragments which appear to be portions of combs, and one of which bears traces of ornamentation; and an article about 3 inches long, apparently the handle of some tool.

The spindle-whorls are formed of different materials, such as Devonian red grit, one of the harder varieties of Triassic sandstone (rocks abundant in the neighbourhood), a somewhat coarse, greenish, schistose rock not found near the district, and Kimmeridge coal. They differ somewhat in dimensions and in workmanship; some being well finished, whilst others are so roughly made as to render it safer perhaps to call them simply "holed stones." With them may be mentioned a large bead, which appears to consist of amber or some analogous substance; and a small, holed, ellipsoidal fragment of limestone, which was perforated probably by some lithodorous mollusk.

The flint-flakes are four in number, two of dark and two of light or white

flint, the latter being the best formed. The light colour is more or less superficial, the centre being of a dark grey.

The charred wood is very abundant. Some specimens are undistinguishable from prepared charcoal, whilst others are obviously nothing more than partially burnt sticks, some of them of considerable size.

Bones are extremely numerous. They are more or less discoloured, and have lost a considerable portion of their weight. It may be doubted whether the entire elements of any skeleton have been found lying together. Amongst them there are the relics of pig, deer, sheep, fox, wolf (?), bat, hare, rabbit, with smaller rodents, birds, and various kinds of fish. Some of them appear to have been exposed to the action of fire.

The land shells are principally various kinds of snail, the larger forms being the most prevalent. They occur in all stages of growth, and thus render it probable that they had established a colony in the cavern. Amongst the marine shells are the limpet, whelk, oyster, cockle, mussel, pecten, solen or razor-shell, and the internal shell of the cuttle-fish, *Sepia officinalis*. From the un rubbed condition of the last, it was probably not found cast ashore on the beach, but taken directly from the cephalopod to which it belonged.

The source of the shells of hazel-nuts is not far to seek. They were no doubt obtained from the wood in which the cavern is situated, and were perhaps carried in by small animals whose homes were under the fallen masses of limestone where the shells were found. Most of them are perforated at one end.

In passing below the black mould we first encounter the stalagmitic breccia. This the workmen carefully break into small fragments, in order to detect any articles of interest imbedded in it. The search, though not very productive, has not been quite fruitless. In the breccia have been found charred wood, marine and land shells, and bones of various animals, some of which perhaps are extinct.

Immediately beneath this cake we enter the red cave-loam, and at once find ourselves amongst the relics of several species of extinct animals. The only differences in the four successive levels in which, as already stated, the red loam is taken out are simply that the first or uppermost is the poorest, and the third, perhaps, the richest in osseous remains; and that the three lower levels contain a large amount of minutely comminuted bone, of which there are very few instances in the uppermost foot. In other respects the levels are the same—everywhere the same in the materials which form the staple of the deposit; in the occurrence of pebbles of various kinds of rock, which differ from those in the overlying black mould only in being less numerous; in the presence of bones in the same condition and representing the same species of animals; and in yielding “flint implements” of the same types. It will not be necessary, therefore, to describe each level separately or in detail.

The bones found below the stalagmite are heavier than those met with above it. This distinction is so well marked and so constant as to be characteristic. It would be easy to assign them to their respective deposits by their specific weights alone. Most of those from the red loam are but little discoloured, indeed some of them are of a chalk-like whiteness. A few, however, occur here and there which have undergone a considerable amount of discoloration, a consequence, probably, and also a proof of a greater degree of exposure before their inhumation. On most of the latter, certain lines and patches of lighter colour not unfrequently present themselves, which

may be likened to such as are sometimes left by mosses or lichens on objects on which they have grown.

A large number of bones, including jaws, teeth, and horns, are scored with teeth-marks, clearly the work of animals of different kinds. Some of the long bones are split longitudinally. Many appear to have been rolled, including most of those which have been gnawed; and in the case of the latter, it is tolerably obvious that the rolling was subsequent to the gnawing. Some of those found beneath the large masses of fallen limestone are in a crushed condition, and thus apparently attest the fact that the deposit on which they lay, and on which the blocks fell, was of a compact nature, and capable of a firm resistance.

The minutely comminuted bone already spoken of, is commonly found converted with loam and stones into a firm breccia. Not unfrequently, however, it occupies the hollow cavities of some of the larger bones. With it there sometimes occurs a cream-coloured substance, which in a few instances has been met also in the form of small detached lumps having a low specific gravity. This, as well as some of the comminuted bone, has been supposed to be of faecal origin.

In cleaning the bones it is frequently found to be impossible to remove entirely the earthy matter from them. They are at least partially invested with a thin film, which defies the brush and water. On drying, however, this matter commonly scales off, and proves to be a paste or paint composed of loam and carbonate of lime, the latter probably derived from drip from the roof.

Large portions of the osseous remains occur in the forms of fragments and mere splinters. The identifiable parts are chiefly teeth, which are extremely numerous. Amongst the Mammals represented, there are certainly the Cave-bear, Cave-lion, Cave-hyæna, Fox, Horse (probably more than one species), Ox, several species of Deer, the tichorhine Rhinoceros, and Mammoth. Remains of the Hyæna are probably the most abundant, after which come those of Rhinoceros and Horse. The relics of the Mammoths (both molars and tusks) are those of very young individuals.

It has already been hinted that "flint implements" occur everywhere in the cave-earth mixed up with the remains of extinct Mammals. Several of them were found in the presence of, and some of them by, the Superintendents. Like the bones, they are least abundant in the uppermost foot, and occur in greatest numbers in the lowest zones. Altogether, and without reckoning doubtful specimens and numerous chips, nearly thirty "implements" have been dug out. Though the designation of "flint" is given to all, some of them are perhaps of chert. Of the flints properly so called, some are of a dark, and others of a light-grey colour, whilst a third kind are almost white, and have a porcellanous aspect. With the exception of three, they are all of the kind known as flakes—flat on one side, and more or less carinated on the other. Some of them are fragments only, others were found broken in the deposit with the parts lying in contact, whilst others again are perfect. Some of the broken specimens of the white variety show that they are not of this colour throughout their entire mass, but have a dark central axis or core. The flakes agree in character with those in the black overlying mould. The excepted three are of chert, and are worked on both sides. They were found in the second, third, and fourth levels; one in each. That from the second foot is about $4\frac{3}{4}$ inches long, and, where widest, $2\frac{1}{2}$ broad. At one end it tapers to a point, and narrows to no more than $\frac{3}{4}$ of an inch at the other. In outline it is rudely a segment of a

curvilinear figure, and is slightly falciform. The inner or concave margin is the cutting edge. Unfortunately the tip of the pointed end was broken off after exhumation. Those from the third and fourth levels are more highly wrought "implements." They are worked to an edge around the entire perimeter. In outline they are rather ovoid than elliptical, being narrower at one end than at the other. That from the third foot measures $4\frac{1}{2}$ inches in length, and its greatest breadth and thickness are respectively $3\frac{1}{4}$ inches and $\frac{3}{4}$ of an inch. That found in the fourth zone, the lowest yet reached, is the most elaborately finished "implement" of the series. It is lighter in colour and somewhat smaller than the preceding two, its dimensions being $3\frac{1}{2}$ inches long, $2\frac{1}{2}$ broad, and $\frac{3}{4}$ in thickness.

Without intending at present to enter on the consideration of all the bearings of the entire evidence produced, the Committee feel at liberty to express their conviction that it is totally impossible to doubt either the human origin of the "implements," or their inoculation, in undisturbed soil, with the remains of the Mammoth, the Cave-bear, and their extinct contemporaries.

Nor are these the only indications of human existence found in the cave-earth. Several small pieces of burnt bone have been met with in the red loam, some of them loose and detached, others of small size and incorporated in the breccia composed of loam, stones, and comminuted bone.

Mention has been made already of the occurrence in the cave-earth of rounded stones not derivable from the limestone hill in which the cavern is situated. It seems probable that at least some of them were selected and taken there by man; though it may not be easy, perhaps, to determine in all cases for what purpose. But, waiving this point, there are two stones which must not be hastily dismissed. The first of them is $4\frac{3}{4}$ inches long, and something less than 1 inch square in the section. It is a mass of hard purplish-grey grit, and is undoubtedly a whetstone, or rather a portion of one. It was found in the first level of the cave-earth, in a small recess or cavity in the northern wall of the chamber, immediately beneath a projecting stratum of limestone *in situ*. In this cavity the stone stood with its longest axis vertical. The Superintendents were inclined to the opinion that it had slipped through a hole into the cavity at a comparatively recent date; and they diligently set to work to find the means of its ingress. Here, however, they were completely foiled. There was no hole or passage, vertical or lateral, by which the cavity could have been entered. Not only, as has been said, was there a thick stratum of limestone *in situ* immediately over the recess, but over this again, as well as over the red loam, there was a thick compact mass of stalagmitic breccia, consisting of large and small pieces of limestone firmly cemented, and having a height of fully 8 feet; the whole of which was removed before the cavity was disclosed or its existence suspected.

The second stone is a rude flattened spheroid, formed from a pebble of coarse, hard, red sandstone, and apparently used for breaking or crushing. Its diameters measure $2\frac{3}{4}$ and $1\frac{3}{4}$ inches. It was found in the second level of the red cave-earth, over which lay an enormous block of limestone, but no stalagmite.

In addition to the pleasure which always attends scientific discovery, the Committee have had the gratification of confirming most of the statements of their predecessors. Any differences observable between the statements now made and those of the earlier investigators arise from defective, not conflicting evidence. For example, the Committee have not yet been so fortunate as to find the remains of *Machairodus latidens*, mentioned and

figured by Mr. M'Enery*, nor of *Hippopotamus major*, alluded to by Prof. Owen† as occurring in the cavern; nor have they found anything in the least degree calculated to bring the statements alluded to into discredit. Again, so far as their researches have gone, the Committee have not, like Mr. Godwin-Austen, found the bones of man mixed up, in undisturbed soil, with those of extinct animals‡; it will be seen, however, that there is no *à priori* improbability in the statement of the distinguished geologist just mentioned; and the Committee would remind such as may be disposed to attach importance to the fact that men's bones are not forthcoming as readily as their implements, that in the black mould, as well as in the red loam of the cavern, the only indications of man's existence are remnants of his handiwork. Pottery, implements and ornaments in bone, metal, and stone, the remnants of his fires, and the relics of his feasts are numerous, and betoken the lapse of at least two milleniums; but here, as well as in the older deposits below, the Committee have met with no vestige of his osseous system.

In conclusion, the Committee would observe that the value of their labours is not to be measured by the discoveries, or rather the rediscoveries, which they have made. They have not only disinterred a valuable body of fact, but with it a confirmation of the concurrent statements of M'Enery, Godwin-Austen, and the Committee of the Torquay Natural History Society; and have thereby more than doubled the amount of trustworthy evidence which they have themselves produced.

Report of a Committee "appointed to report on the changes which they may consider desirable to make, if any, in the Rules of Zoological Nomenclature drawn up by Mr. H. E. Strickland, at the instance of the British Association at their Meeting in Manchester in 1842."

REFORM of the Nomenclature of Zoology was a subject which occupied much of the time of the late Hugh E. Strickland§. It was his object that this reform should be brought forward under the auspices of the British Association, and at a meeting of the Council of that body, held in London upon 11th of February, 1842, it was resolved—"That with a view of securing attention to the following important subject, a Committee, consisting of Mr. C. Darwin, Professor Henslow, Rev. L. Jenyns, Mr. W. Ogilby, Mr. J. Phillips, Dr. Richardson, Mr. H. E. Strickland (reporter), Mr. J. O. Westwood, be appointed, to consider of the rules by which the nomenclature of zoology may be established on a uniform and permanent basis; the Report to be presented to the Zoological Section, and submitted to its committee at the Manchester Meeting"¶.

This Committee met at various times in London, and the following gentlemen were added to it, and assisted in its labours:—W. J. Broderip, Professor Owen, W. E. Shuckard, G. R. Waterhouse, and W. Yarrell. An outline of the proposed code was drawn up and circulated, and many valuable

* Cavern Researches, p. 32, and plate F. (8vo Edition).

† British Fossil Mammals and Birds, p. 410 (1846).

‡ Trans. Geol. Soc., Second Series, vol. vi. part 2. pp. 444 & 446.

§ See Memoirs of Hugh Edwin Strickland, by Sir W. Jardine, Bart., pp. clxxv. and 375.

¶ Report of Twelfth Meeting of the British Association held at Manchester, June 1842,

suggestions were received from eminent zoologists at home and abroad. The "plan" was further considered by the Committee during the Meeting at Manchester, "and the Committee having thus given their best endeavours to maturing the plan, beg now to submit it to the approval of the British Association under the title of—'Series of Propositions for rendering the nomenclature of zoology uniform and permanent'""*.

The propositions were printed in the Reports of the British Association, and a grant of money was voted to print copies for circulation. The rules thus laid down were very generally adopted by zoologists, both in this country and abroad; but in Great Britain having been printed only in the volumes of the British Association, 'Annals of Natural History,' and 'Philosophical Magazine'†, or depending on private circulation, it was deemed advisable that greater publicity should be given to them, and at the Meeting at Oxford in 1860 it was resolved, that "The surviving members of the Committee appointed in 1842, viz., Mr. C. Darwin, Rev. Professor Henslow, Rev. L. Jenyns, Mr. W. Ogilby, Professor Phillips, Sir John Richardson, Mr. J. O. Westwood, Professor Owen, Mr. W. E. Shuckard, and Mr. G. R. Waterhouse, for the purpose of preparing rules for the establishment of a Uniform Zoological Nomenclature, be reappointed, with Sir W. Jardine, Bart., and Dr. Selater. That Sir W. Jardine, Bart., be the Reporter, and that the sum of £10 be placed at their disposal for the purpose of revising and reprinting the Rules"‡.

From the difficulty of bringing such a Committee together, nothing was done since the time of its appointment; but the resolution and a grant of money were again renewed at the late Meeting in Newcastle, as follows:—"That Sir W. Jardine, A. R. Wallace, J. E. Gray, Professor Babington, Dr. Francis, Dr. Selater, C. Spence Bate, P. P. Carpenter, Dr. J. D. Hooker, Professor Balfour, H. T. Stainton, J. Gwyn Jeffreys, A. Newton, Professor T. H. Huxley, Professor Allman, and G. Bentham, be a Committee, with power to add to their number, to report on the changes, *if any*, which they may consider it desirable to make in the Rules of Nomenclature drawn up at the instance of the Association by Mr. H. E. Strickland and others, with power to reprint these Rules, and to correspond with foreign naturalists and others on the best means of ensuring their general adoption, and that the sum of £15 be placed at their disposal for the purpose."

Accordingly the Rules, as originally approved of, were reprinted, and zoologists were requested "to examine them carefully, and to communicate any suggestions for alteration or improvement, on or before the 1st of June, 1864, to *Sir William Jardine, Bart., Jardine Hall, by Lockerby, N.B.*, who will consult with the members of the Committee, and report upon the subject at the next Meeting of the British Association appointed to be held at Bath."

From the press of business at Bath the Committee did little there to complete further the code of Zoological Nomenclature, and I was directed to take some opportunity while in London to call together as many members of the Committee as possible. Accordingly in the month of June last I sent

* Report of Twelfth Meeting, 1842, p. 106.

† At the Scientific Congress held in 1843 at Padua, the late Prince C. L. Buonaparte submitted to the meeting an Italian translation of the 'British Association's Code of Rules,' which was generally approved of. A French translation of the Report appeared in the scientific journal 'L'Institut,' in which paper much stress was laid on the importance of the measure. A review of it was also printed in the 'American Journal of Science.'

‡ Reports of the British Association held at Oxford, 1860, p. xlv.

a circular to the following members that I considered were within comparatively easy reach, and who I thought might be able to attend in London without much inconvenience, viz., Mr. Gwyn Jeffreys, Mr. Wallace, Dr. Gray, Professor Babington, Dr. Francis, Dr. Selater, Dr. J. Hooker, Mr. Stainton, Professor Huxley, Mr. A. Newton, and Mr. G. Bentham. Mr. Gwyn Jeffreys kindly permitted this meeting to be held at his house in Devonshire-place, and it was attended by myself, Mr. Gwyn Jeffreys, Mr. Wallace, and Dr. Selater; the other gentlemen who had been invited sending apologies that from various causes they were unable to come up to London or to attend. They, however, expressed themselves generally favourable to some code of rules being adopted.

Professor Babington having returned his printed copy of the rules with his observations written on the margin, the Committee were fully in possession of his views. Mr. Wallace had brought with him a written memorandum containing notes of what he thought could be altered or modified with advantage. The members present then read over the printed rules and recommendations one by one, and carefully compared them with the memoranda above mentioned, as well as with many letters from other naturalists, and the observations made upon each were taken down at the time. The recommendations of the Committee, which I shall presently read to you, have been based upon these observations, and upon the conferences and discussions held at Birmingham during the present Meeting.

Since the time that Mr. H. E. Strickland's Rules and Recommendations were printed in the Reports of the British Association, zoological nomenclature has not been improved. Whether it is from the rules and recommendations not being sufficiently well known, or from an idea that no one has any right to interfere with or make rules for others, many gentlemen appear to cast them away, and do not recognize them at all, while others accept or reject just what pleases themselves; in consequence many very objectionable names have been given, and a very base coinage and spurious combinations have been going on. The Committee does not allude to very long or harsh sounding names, though they are much to be deprecated even when classically compounded; but they object to *indelicate names*, or to such compounds as *Malherbipicus*, *Kaupifalco*, *Zebripicus*, &c.; or, when a new form in the genus *Procellaria* is thought to be discovered, and honour is intended to be done to a distinguished navigator, such a word as *Cookilaria* is proposed; or, when provincial names are attempted to be Latinized, as in the case of a fish commonly known as the "*Tom Cod*," which is entered in our systems under the scientific (?) name of *Morrhua tomcodus*. These may be said to be extreme examples, but hundreds might be given, and it is the opinion of the Committee that the only way to deal with such names is to reject them altogether.

In this condition of our zoological nomenclature, then, it is of the greatest importance that some general code of rules should be adopted and acted upon. The Committee were perfectly agreed upon this point, but on calling them together during the present Meeting of the British Association, the botanists arrived at the conclusion that, having long acted in concert upon the rules laid down by Linnæus in the '*Philosophia Botanica*,' and by Sir James E. Smith, DeCandolle, and others, it was unnecessary for them to have Botany included in the Stricklandian code; at the same time they were sensible that some generally recognized code would be of the utmost importance to zoology. The Committee therefore are of opinion and recommend:—

- I. That Botany should not be introduced into the Strickland rules and recommendations.
- II. That the permanency of names and convenience of practical application being the two chief requisites in any code of rules for scientific nomenclature, it is not advisable to disturb by any material alterations the rules of zoological nomenclature which were authorized by Section D at the Meeting of the British Association at Manchester in 1842.
- III. The Committee are of opinion, after much deliberation, that the XIIth edition of the 'Systema Naturæ' is that to which the limit of time should apply, viz. 1766. But as the works of Artedi and Scopoli have already been extensively used by ichthyologists and entomologists, it is recommended that the names contained in or used from these authors should not be affected by this provision. This is particularly requisite as regards the generic names of Artedi afterwards used by Linnæus himself.

In Mr. H. E. Strickland's original draft of these Rules and Recommendations the edition of Linnæus was left blank, and the XIIth was inserted by the Manchester Committee. This was done not as being the first in which the Binomial nomenclature had been used, as it commenced with the Xth, but as being the last and most complete edition of Linnæus's works, and containing many species the Xth did not. For these reasons it is now confirmed by this Committee, and also because these rules having been used and acted upon for twenty-three years, if the date were altered now, many changes of names would be required, and in consequence much confusion introduced.

- IV. In Rule 13th, "*Specific names, when adopted as generic, must be changed.*" The Committee agree that it is exceedingly injudicious to adopt a specific name as a generic name, but they are of opinion that where this has been done, it is the *generic name* which must be thrown aside, not the old specific name, and that this rule should be so altered as to meet this.
- V. The recommendations under "*Classes of objectionable names,*" as already pointed out, cannot be too carefully attended to. *Specific names* from persons have already been sufficiently prostituted, and personal *generic* names have increased to a large and undeserving extent. The handing down the name of a naturalist by a genus has always been considered as the highest honour that could be given, and should never be bestowed lightly*.
- VI. The recommendation, "*Specific names to be written with a small initial.*" The Committee propose that this recommendation should be omitted. It is not of great importance, and may be safely left to naturalists to deal with as they think fit.

These are the chief alterations and modifications the Committee have to suggest. It is scarcely possible to make any code of rules for a subject so extensive as zoology either perfect in itself or such as will meet the opinions of every one. It must be a matter of compromise, and as working by *no rules* is creating great confusion and an immense increase in synonymy, the Committee would ask this Section to approve their present report or finding,

* "Hoc unicum et summum præmium laboris, sancte servandum, et caste dispensandum ad incitamentum et ornamentum Botanices."—Phil. Botan., p. 171.

and to give their sanction to these Rules and Recommendations as now proposed to be modified.

Signed on the part of the members of Committee
present at Birmingham* by

WM. JARDINE, *Reporter.*

On the preceding Report being read to Section D, upon Tuesday, 19th September, the following motion was made and carried unanimously:—

Moved by Mr. Gwyn Jeffreys, seconded by Dr. Selater,—*That the Report now read be approved of and adopted by the Section, and that the Rules or propositions, as thereby altered and amended, be printed in the Reports of the British Association and recommended for the general use of zoologists.*

PART I.

RULES FOR RECTIFYING THE PRESENT ZOOLOGICAL NOMENCLATURE.

[*Limitation of the Plan to Systematic Nomenclature.*]

In proposing a measure for the establishment of a permanent and universal zoological nomenclature, it must be premised that we refer solely to the Latin or systematic language of zoology. We have nothing to do with vernacular appellations. One great cause of the neglect and corruption which prevails in the scientific nomenclature of zoology, has been the frequent and often exclusive use of vernacular names in lieu of the Latin binomial designations, which form the only legitimate language of systematic zoology. Let us then endeavour to render perfect the Latin or Linnæan method of nomenclature, which, being far removed from the scope of national vanities and modern antipathies, holds out the only hope of introducing into zoology that grand desideratum, an universal language.

[*Law of Priority the only effectual and just one.*]

It being admitted on all hands that words are only the conventional signs of ideas, it is evident that language can only attain its end effectually by being permanently established and generally recognized. This consideration ought, it would seem, to have checked those who are continually attempting to subvert the established language of zoology by substituting terms of their own coinage. But, forgetting the true nature of language, they persist in confounding the *name* of a species or group with its *definition*; and because the former often falls short of the fulness of expression found in the latter, they cancel it without hesitation, and introduce some new term which appears to them more characteristic, but which is utterly unknown to the science, and is therefore devoid of all authority†. If these persons were to object to such names of men as *Long, Little, Armstrong, Golightly, &c.*, in cases where they fail to apply to the individuals who bear them, or should complain of the names *Gough, Lawrence, or Harvey*, that they were devoid of meaning, and should hence propose to change them for more characteristic appellations, they would not act more unphilosophically or inconsiderately than they do in the case before us; for, in truth, it matters not in the least by what conventional sound we agree to designate an individual object, provided the sign to be employed be stamped with such an authority as will suffice to

* The Members of the Committee present at Birmingham were A. R. Wallace, Professor Babington, Dr. Francis, Dr. Selater, C. Spence Bate, P. P. Carpenter, Professor Balfour, H. T. Stainton, J. Gwyn Jeffreys, A. Newton, G. Bentham, and Sir W. Jardine, Bart. (Reporter).

† Linnæus says on this subject, “*Abstinendum ab hac innovatione quæ nunquam cessaret, quin indies aptiora detegerentur ad infinitum.*”

make it pass current. Now in zoology no one person can subsequently claim an authority equal to that possessed by the person who is the first to define a new genus or describe a new species; and hence it is that the name originally given, even though it may be inferior in point of elegance or expressiveness to those subsequently proposed, ought as a general principle to be permanently retained. To this consideration we ought to add the injustice of erasing the name originally selected by the person to whose labours we owe our first knowledge of the object; and we should reflect how much the permission of such a practice opens a door to obscure pretenders for dragging themselves into notice at the expense of original observers. Neither can an author be permitted to alter a name which he himself has once published, except in accordance with fixed and equitable laws. It is well observed by Decandolle, “L’auteur même qui a le premier établi un nom n’a pas plus qu’un autre le droit de le changer pour simple cause d’impropriété. La priorité en effet est un terme fixe, positif, qui n’admet rien, ni d’arbitraire ni de partial.”

For these reasons, we have no hesitation in adopting as our fundamental maxim, the “law of priority,” viz.,

§ 1. The name originally given by the founder of a group or the describer of a species should be permanently retained, to the exclusion of all subsequent synonyms (with the exceptions about to be noticed).

Having laid down this principle, we must next inquire into the limitations which are found necessary in carrying it into practice.

[*Not to extend to authors older than Linnæus.*]

As our subject matter is strictly confined to the *binomial system of nomenclature*, or that which indicates species by means of two Latin words, the one generic, the other specific, and as this invaluable method originated solely with Linnæus, it is clear that, as far as species are concerned, we ought not to attempt to carry back the principle of priority beyond the date of the 12th edition of the ‘*Systema Naturæ*,’ 1766. Previous to that period, naturalists were wont to indicate species not by a *name* comprised in one word, but by a *definition* which occupied a sentence, the extreme verbosity of which method was productive of great inconvenience. It is true that one word sometimes sufficed for the definition of a species, but these rare cases were only binomial by accident and not by principle, and ought not therefore in any instance to supersede the binomial designations imposed by Linnæus.

The same reasons apply also to generic names. Linnæus was the first to attach a definite value to genera, and to give them a systematic character by means of exact definitions; and therefore, although the *names* used by previous authors may often be applied with propriety to modern genera, yet in such cases they acquire a new meaning, and should be quoted on the authority of the first person who used them in this secondary sense. It is true, that several of the old authors made occasional approaches to the Linnæan exactness of generic definition, but still these were but partial attempts; and it is certain that if in our rectification of the binomial nomenclature we once trace back our authorities into the obscurity which preceded the epoch of its foundation, we shall find no resting-place or fixed boundary for our researches. The nomenclature of Ray is chiefly derived from that of Gesner and Aldrovandus, and from these authors we might proceed backward to Ælian, Pliny, and Aristotle, till our zoological studies would be frittered away amid the refinements of classical learning*.

* “*Quis longo ævo recepta vocabula commutaret hodie?*”—*Linnæus*.

We therefore recommend the adoption of the following proposition :—

§ 2. The binomial nomenclature having originated with Linnæus, the law of priority in respect of that nomenclature, is not to extend to the writings of antecedent authors, and therefore specific names published before 1766 cannot be used to the prejudice of names published since that date.

[It should be here explained, that as the works of Artedi and Scopoli have already been extensively used by ichthyologists and entomologists, the names contained in or used from these authors should not be affected by this provision. This is particularly requisite as regards the generic names of Artedi, afterwards used by Linnæus himself. Brisson also, who was a contemporary of Linnæus and acquainted with the ‘Systema Naturæ,’ defined and published certain genera of birds which are *additional* to those in the twelfth edition of Linnæus’s works, and which are therefore of perfectly good authority. But Brisson still adhered to the old mode of designating species by a sentence instead of a word, and therefore while we retain his defined genera, we do not extend the same indulgence to the titles of his species, even when the latter are accidentally binomial in form. For instance, the *Perdix rubra* of Brisson is the *Tetrao rufus* of Linnæus; therefore as we in this case retain the generic name of Brisson and the specific name of Linnæus, the correct title of the species would be *Perdix rufa* (Linn.).

[*Generic names not to be cancelled in subsequent subdivisions.*]

As the number of known species which form the groundwork of zoological science is always increasing, and our knowledge of their structure becomes more complete, fresh generalizations continually occur to the naturalist, and the number of genera and other groups requiring appellations is ever becoming more extensive. It thus becomes necessary to subdivide the contents of old groups, and to make their definitions continually more restricted. In carrying out this process, it is an act of justice to the original author that his generic name should never be lost sight of; and it is no less essential to the welfare of the science, that all which is sound in its nomenclature should remain unaltered amid the additions which are continually being made to it. On this ground we recommend the adoption of the following rule :—

§ 3. A generic name, when once established, should never be cancelled in any subsequent subdivision of the group, but retained in a restricted sense for one of the constituent portions.

[*Generic names to be retained for the typical portion of the old genus.*]

When a genus is subdivided into other genera, the original name should be retained for that portion of it which exhibits in the greatest degree its essential characters as at first defined. Authors frequently indicate this by selecting some one species as a fixed point of reference, which they term the “type of the genus.” When they omit doing so, it may still in many cases be correctly inferred that the *first* species mentioned on their list, if found accurately to agree with their definition, was regarded by them as the type. A specific name, or its synonyms, will also often serve to point out the particular species which by implication must be regarded as the original type of a genus. In such cases we are justified in restoring the name of the old genus to its typical signification, even when later authors have done otherwise. We submit therefore that

§ 4. The generic name should always be retained for that portion of the original genus which was considered typical by the author.

Example.—The genus *Picumnus* was established by Temminck, and in-

cluded two groups, one with four toes, the other with three, the *former* of which was regarded by the author as typical. Swainson, however, in raising these groups at a later period to the rank of genera, gave a new name, *Asthenurus*, to the *former* group, and retained *Picumnus* for the *latter*. In this case we have no choice but to restore the name *Picumnus*, Temm., to its correct sense, cancelling the name *Asthenurus*, Sw., and imposing a new name on the three-toed group which Swainson had called *Picumnus*.

[When no type is indicated, then the original name is to be kept for that subsequent subdivision which first received it.]

Our next proposition seems to require no explanation:—

§ 5. When the evidence as to the original type of a genus is not perfectly clear and indisputable, then the person who first subdivides the genus may affix the original name to any portion of it at his discretion, and no later author has a right to transfer that name to any other part of the original genus.

[A later name of the same extent as an earlier to be wholly cancelled.]

When an author infringes the law of priority by giving a new name to a genus which has been properly defined and named already, the only penalty which can be attached to this act of negligence or injustice, is to expel the name so introduced from the pale of the science. It is not right, then, in such cases to restrict the meaning of the latter name so that it may stand side by side with the earlier one, as has sometimes been done. For instance, the genus *Monaulus*, Vieill. 1816, is a precise equivalent to *Lophophorus*, Temm. 1813, both authors having adopted the same species as their type, and therefore, when the latter genus came in the course of time to be divided into two, it was incorrect to give the condemned name *Monaulus* to one of the portions. To state this succinctly:—

§ 6. When two authors define and name the same genus, *both making it exactly of the same extent*, the later name should be cancelled *in toto*, and not retained in a modified sense*.

This rule admits of the following exception:—

§ 7. Provided, however, that if these authors select their respective types from different sections of the genus, and these sections be afterwards raised into genera, then both these names may be retained in a restricted sense for the new genera respectively.

Example—The names *Edemia* and *Melanetta* were originally coextensive synonyms, but their respective types were taken from different sections which are now raised into genera, distinguished by the above titles.

[No special rule is required for the cases in which the later of two generic names is so defined as to be *less extensive* in signification than the earlier, for if the later includes the type of the earlier genus, it would be cancelled by the operation of § 4; and if it does not include that type, it is in fact a distinct genus.]

But when the later name is *more extensive* than the earlier, the following rule comes into operation:—

[A later name equivalent to several earlier ones is to be cancelled.]

The same principle which is involved in § 6 will apply to § 8.

* These discarded names may, however, be *tolerated*, if they have been afterwards proposed in a totally new sense, though we trust that in future no one will *knowingly* apply an old name, whether now adopted or not, to a new genus. (See proposition, *q. infra*.)

§ 8. If the later name be so defined as to be equal in extent to two or more previously published genera, it must be cancelled *in toto*.

Example.—*Psarocolius*, Wagl. 1827, is equivalent to five or six genera previously published under other names, therefore *Psarocolius* should be cancelled.

If these previously published genera be *separately adopted* (as is the case with the equivalents of *Psarocolius*), their original names will of course prevail; but if we follow the later author in combining them into one, the following rule is necessary:—

[*A genus compounded of two or more previously proposed genera whose characters are now deemed insufficient, should retain the name of one of them.*]

It sometimes happens that the progress of science requires two or more genera, founded on insufficient or erroneous characters, to be combined together into one. In such cases the law of priority forbids us to cancel *all* the original names and impose a *new* one on this compound genus. We must therefore select some one species as a type or example, and give the generic name which it formerly bore to the whole group now formed. If these original generic names differ in date, the oldest one should be the one adopted.

§ 9. In compounding a genus out of several smaller ones, the earliest of them, if otherwise objectionable, should be selected, and its former generic name be extended over the new genus so compounded.

Example.—The genera *Accentor* and *Prunella* of Vieillot not being considered sufficiently distinct in character, are now united under the general name of *Accentor*, that being the earliest.

We now proceed to point out those few cases which form exceptions to the law of priority, and in which it becomes both justifiable and necessary to alter the names originally imposed by authors.

[*A name should be changed when previously applied to another group which still retains it.*]

It being essential to the binomial method to indicate objects in natural history by means of *two words* only, without the aid of any further designation, it follows that a generic name should only have one meaning—in other words, that two genera should never bear the same name. For a similar reason, no two species in the same genus should bear the same name. When these cases occur, the later of the two duplicate names should be cancelled, and a new term, or the earliest synonym, if there be any, substituted. When it is necessary to form new words for this purpose, it is desirable to make them bear some analogy to those which they are destined to supersede, as where the genus of birds *Plectorhynchus*, being preoccupied in Ichthyology, is changed to *Plectorhamphus*. It is, we conceive, the bounden duty of an author, when naming a new genus, to ascertain by careful search that the name which he proposes to employ has not been previously adopted in other departments of natural history*. By neglecting this precaution he is liable to have the name altered and his authority superseded by the first subsequent author who may detect the oversight, and for this result, however unfortunate, we fear there is no remedy, though such cases would be less frequent

* This laborious and difficult research is now greatly facilitated by the very useful work of M. Agassiz, entitled "*Nomenclator Zoologicus*," and "*Index Universalis*" to that work.

if the detectors of these errors would, as an act of courtesy, point them out to the author himself, if living, and leave it to him to correct his own inadvertencies. This occasional hardship appears to us to be a less evil than to permit the practice of giving the same generic name *ad libitum* to a multiplicity of genera. We submit, therefore, that

§ 10. A name should be changed which has before been proposed for some other genus in zoology or botany, or for some other species in the same genus, when still retained for such genus or species.

[*A name whose meaning is glaringly false may be changed.*]

Our next proposition has no other claim for adoption than that of being a concession to human infirmity. If such proper names of places as Covent Garden, Lincoln's Inn Fields, Newcastle, Bridgewater, &c., no longer suggest the ideas of gardens, fields, castles, or bridges, but refer the mind with the quickness of thought to the particular localities which they respectively designate, there seems no reason why the proper names used in natural history should not equally perform the office of correct indication, even when their etymological meaning may be wholly inapplicable to the object which they typify. But we must remember that the language of science has but a limited currency, and hence the words which compose it do not circulate with the same freedom and rapidity as those which belong to every-day life. The attention is consequently liable in scientific studies to be diverted from the contemplation of the thing signified to the etymological meaning of the sign, and hence it is necessary to provide that the latter shall not be such as to propagate actual error. Instances of this kind are indeed very rare, and in some cases, such as that of *Monodon*, *Caprimulgus*, *Paradisea apoda* and *Monoculus*, they have acquired sufficient currency no longer to cause error, and are therefore retained without change. But when we find a Batrachian reptile named in violation of its true affinities *Mastodonsaurus*, a Mexican species termed (through erroneous information of its habitat) *Picus cafer*, or an olive-coloured one *Muscicapa atra*, or when a name is derived from an accidental monstrosity, as in *Picus semirostris* of Linnæus, and *Helix disjuncta* of Turton, we feel justified in cancelling these names, and adopting that synonym which stands next in point of date. At the same time we think it right to remark that this privilege is very liable to abuse, and ought therefore to be applied only to extreme cases and with great caution. With these limitations we may concede that

§ 11. A name may be changed when it implies a false proposition which is likely to propagate important errors.

[*Names not clearly defined may be changed.*]

Unless a species or group is intelligibly defined when the name is given, it cannot be recognized by others, and the signification of the name is consequently lost. Two things are necessary before a zoological term can acquire any authority, viz., *definition* and *publication*. Definition properly implies a distinct exposition of essential characters, and in all cases we conceive this to be indispensable, although some authors maintain that a mere enumeration of the component species, or even of a single type, is sufficient to authenticate a genus. To constitute *publication*, nothing short of the insertion of the above particulars in a printed book can be held sufficient. Many birds, for instance, in the Paris and other continental museums, shells in the British Museum (in Dr. Leach's time), and fossils in the Scarborough and other public collections, have received MS. names, which will be of no

authority until they are published with characters*. Nor can any unpublished descriptions, however exact (such as those of Forster, which are still shut up in a MS. at Berlin), claim any right of priority till published, and then only from the date of their publication. The same rule applies to cases where groups or species are published, but not defined, as in some museum catalogues, and in Lesson's 'Traité d'Ornithologie,' where many species are enumerated by name, without any description or reference by which they can be identified. Therefore,—

§ 12. A name which has never been clearly defined in some published work should be changed for the earliest name by which the object shall have been so defined.

[*Specific names, when adopted as generic, must be changed.*]

The necessity for the following rule will be best illustrated by an example. The *Corvus pyrrhcorax*, Linn., was afterwards advanced to a genus under the name of *Pyrrhcorax*. Temminck adopts this generic name, and also retains the old specific one, so that he terms the species *Pyrrhcorax pyrrhcorax*. The inelegance of this method is so great as to demand a change of the generic name. We propose, therefore, that

§ 13. A specific name must not be altered in order to use that name for the genus; where this has been already done the old specific name must be restored, and a new generic name given to prevent an unharmonious repetition.

N.B.—It will be seen, however, below that we strongly object to the further continuance of this practice of elevating specific names into generic.

[*Latin orthography to be adhered to.*]

On the subject of orthography it is necessary to lay down one proposition,—

§ 14. In writing zoological names, the rules of Latin orthography must be adhered to.

In Latinizing Greek words there are certain rules of orthography known to classical scholars which must never be departed from. For instance, the names which modern authors have written *Aipucnemia*, *Zenophasia*, *poiocephala*, must, according to the laws of etymology, be spelt *Æpycnemia*, *Xenophasia*, and *pæocephala*. In Latinizing modern words the rules of classical usage do not apply, and all that we can do is to give to such terms as classical an appearance as we can, consistently with the preservation of their etymology. In the case of European words whose orthography is fixed, it is best to retain the original form, even though it may include letters and combinations unknown in Latin. Such words, for instance, as *Woodwardi*, *Knighti*, *Bullocki*, *Eschscholtzi*, would be quite unintelligible if they were Latinized into *Vudvardi*, *Cnichti*, *Bulloci*, *Essolzi*, &c. But words of barbarous origin, having no fixed orthography, are more pliable, and hence, when adopted into the Latin, they should be rendered as classical in appearance as is consistent with the preservation of their original sound. Thus the words *Tockus*, *awsuree*, *argoondah*, *kundoo*, &c., should, when Latinized, have been written *Toccus*, *ausure*, *argunda*, *cundu*, &c. Such words ought, in all practicable cases, to have a Latin termination given them, especially if they are used generically.

In Latinizing proper names, the simplest rule appears to be to use the termination *-us*, genitive *-i*, when the name ends with a consonant, as in

* These MS. names are in all cases liable to create confusion, and it is therefore much to be desired that the practice of using them should be avoided in future.

the above examples ; and *-ius*, gen. *-ii*, when it ends with a vowel, as, *Latreille*, *Latreillii*, &c.

In converting Greek words into Latin the following rules must be attended to :—

Greek.	Latin.		Greek.	Latin.
<i>ai</i> becomes	<i>æ</i> .		<i>θ</i> becomes	<i>th</i> .
<i>ei</i> „	<i>i</i> .		<i>φ</i> „	<i>ph</i> .
<i>os</i> terminal,	<i>us</i> .		<i>χ</i> „	<i>ch</i> .
<i>ov</i> „	<i>um</i> .		<i>κ</i> „	<i>c</i> .
<i>ov</i> becomes	<i>u</i> .		<i>γχ</i> „	<i>nch</i> .
<i>oi</i> „	<i>œ</i> .		<i>γγ</i> „	<i>ng</i> .
<i>v</i> „	<i>y</i> .		<i>ε</i> „	<i>h</i> .

When a name has been erroneously written and its orthography has been afterwards amended, we conceive that the authority of the original author should still be retained for the name, and not that of the person who makes the correction.

PART II.

RECOMMENDATIONS FOR IMPROVING THE ZOOLOGICAL NOMENCLATURE IN FUTURE.

The above propositions are all which, in the present state of the science, it appears practicable to invest with the character of laws. We have endeavoured to make them as few and simple as possible, in the hope that they may be the more easily comprehended and adopted by naturalists in general. We are aware that a large number of other regulations, some of which are hereafter enumerated, have been proposed and acted upon by various authors who have undertaken the difficult task of legislating on the subject ; but as the enforcement of such rules would in many cases undermine the invaluable principle of priority, we do not feel justified in adopting them. At the same time we fully admit that the rules in question are, for the most part, founded on just criticism, and therefore, though we do not allow them to operate retrospectively, we are willing to retain them for future guidance. Although it is of the first importance that the principle of priority should be held paramount to all others, yet we are not blind to the desirableness of rendering our scientific language palatable to the scholar and the man of taste. Many zoological terms, which are now marked with the stamp of perpetual currency, are yet so far defective in construction, that our inability to remove them without infringing the law of priority may be a subject of regret. With these terms we cannot interfere, if we adhere to the principles above laid down ; nor is there even any remedy, if authors insist on infringing the rules of good taste by introducing into the science words of the same inelegant or unclassical character in future. But that which cannot be enforced by law may, in some measure, be effected by persuasion ; and with this view we submit the following propositions to naturalists, under the title of *Recommendations for the Improvement of Zoological Nomenclature in future*.

[*The best names are Latin or Greek characteristic words.*]

The classical languages being selected for zoology, and words being more easily remembered in proportion as they are expressive, it is self-evident that

§ A. The *best* zoological names are those which are derived from the Latin or Greek, and express some distinguishing characteristic of the object to which they are applied.

[*Classes of objectionable names.*]

It follows from hence that the following classes of words are more or less objectionable in point of taste, though, in the case of *genera*, it is often necessary to use them, from the impossibility of finding characteristic words which have not before been employed for other genera. We will commence with those which appear the least open to objection, such as

a. Geographical names.—These words being for the most part adjectives can rarely be used for *genera*. As designations of *species* they have been so strongly objected to, that some authors (Wagler, for instance) have gone the length of substituting fresh names wherever they occur; others (*e.g.* Swainson) will only tolerate them where they apply *exclusively*. We are by no means exposed to go to this length. It is not the less true that the *Hirundo javanica* is a Javanese bird, even though it may occur in other countries also, and though other species of *Hirundo* may occur in Java. The utmost that can be urged against such words is, that they do not tell the *whole truth*. However, as so many authors object to this class of names, it is better to avoid giving them, except where there is reason to believe that the species is confined to the country whose name it bears.

b. Barbarous names.—Some authors protest strongly against the introduction of exotic words into our Latin nomenclature, others defend the practice with equal warmth. We may remark, first, that the practice is not contrary to classical usage, for the Greeks and Romans did occasionally, though with reluctance, introduce barbarous words in a modified form into their respective languages. Secondly, the preservation of trivial names which animals bear in their native countries is often of great use to the traveller in aiding him to discover and identify species. We do not therefore consider, if such words have a Latin termination given to them, that the occasional and judicious use of them as scientific terms can be justly objected to.

c. Technical names.—All words expressive of trades and professions have been by some writers excluded from zoology, but without sufficient reason. Words of this class, *when carefully chosen*, often express the peculiar characters and habits of animals in a metaphorical manner, which is highly elegant. We may cite the generic terms *Arvicola*, *Lanius*, *Pastor*, *Tyrannus*, *Regulus*, *Ploceus*, &c., as favourable examples of this class of names.

d. Mythological or historical names.—When these have no perceptible reference or allusion to the characters of the object on which they are conferred, they may properly be regarded as unmeaning and in bad taste. Thus the generic names *Lesbia*, *Leilus*, *Remus*, *Corydon*, *Pusiphae*, have been applied to a Humming bird, a Butterfly, a Beetle, a Parrot, and a Crab respectively, without any perceptible association of ideas. But mythological names may sometimes be used as generic with the same propriety as technical ones, in cases where a direct allusion can be traced between the narrated actions of a personage and the observed habits or structure of an animal. Thus when the name *Progne* is given to a Swallow, *Clotho* to a Spider, *Hydra* to a Polyp, *Athene* to an Owl, *Nestor* to a grey-headed Parrot, &c., a pleasing and beneficial connexion is established between classical literature and physical science.

e. Comparative names.—The objections which have been raised to words of this class are not without foundation. The names, no less than the definitions of objects, should, where practicable, be drawn from positive and self-evident characters, and not from a comparison with other objects, which may be less known to the reader than the one before him. Specific names expressive of comparative size are also to be avoided, as they may be rendered inaccurate by the after discovery of additional species. The names *Picoides*,

Emberizoides, *Pseudoluscinia*, *rubeculoides*, *maximus*, *minor*, *minimus*, &c., are examples of this objectionable practice.

f. Generic names compounded from other genera.—These are in some degree open to the same imputation as comparative words; but as they often serve to express the position of a genus as intermediate to, or allied with, two other genera, they may occasionally be used with advantage. Care must be taken not to adopt such compound words as are of too great length, and not to corrupt them in trying to render them shorter. The names *Gallopavo*, *Tetraogallus*, *Gypaetos*, are examples of the appropriate use of compound words.

g. Specific names derived from persons.—So long as these complimentary designations are used with moderation, and are restricted to persons of eminence as scientific zoologists, they may be employed with propriety in cases where expressive or characteristic words are not to be found. But we fully concur with those who censure the practice of naming species after persons of no scientific reputation, as curiosity dealers (e. g. *Canivetti*, *Boissonneau*), Peruvian priestesses (*Cora*, *Amazilia*), or Hottentots (*Klassi*).

h. Generic names derived from persons.—Words of this class have been extensively used in botany, and therefore it would have been well to have excluded them wholly from zoology, for the sake of obtaining a *memoria technica* by which the name of a genus would at once tell us to which of the kingdoms of nature it belonged. Some personal generic names have, however, crept into zoology, as *Cuvieria*, *Mulleria*, *Rossia*, *Lessonia*, &c., but they are rare in comparison with those of botany, and it is perhaps desirable not to add to their number.

i. Names of harsh and inelegant pronunciation.—These words are grating to the ear, either from inelegance of form, as *Huhua*, *Yuhina*, *Cracirex*, *Eschscholtzi*, or from too great length, as *chirostrongylostinus*, *Opetiorhynchus*, *brachypodioides*, *Thecodontosaurus*. It is needless to enlarge on the advantage of consulting euphony in the construction of our language. As a general rule it may be recommended to avoid introducing words of more than five syllables.

k. Ancient names of animals applied in a wrong sense.—It has been customary, in numerous cases, to apply the names of animals found in classic authors at random to exotic genera or species which are wholly unknown to the ancients. The names *Cebus*, *Callithrix*, *Spiza*, *Kitta*, *Struthus*, are examples. This practice ought by no means to be encouraged. The usual defence for it is, that it is impossible now to identify the species to which the name was anciently applied. But it is certain that if any traveller will take the trouble to collect the vernacular names used by the modern Greeks and Italians for the Vertebrata and Mollusca of southern Europe, the meaning of the ancient names may in most cases be determined with the greatest precision. It has been well remarked that a Cretan fisher-boy is a far better commentator on Aristotle's 'History of Animals' than a British or German scholar. The use, however, of ancient names, *when correctly applied*, is most desirable, for "in framing scientific terms, the appropriation of old words is preferable to the formation of new ones"*.

l. Adjective generic names.—The names of genera are in all cases essentially substantive, and hence adjective terms cannot be employed for them without doing violence to grammar. The generic names *Hians*, *Criniger*, *Cursorius*, *Nitidula*, &c., are examples of this incorrect usage.

m. Hybrid names.—Compound words, whose component parts are taken from two different languages, are great deformities in nomenclature, and naturalists should be especially guarded not to introduce any more such terms

* Whewell, Phil. Ind. Sc. vol. i. p. lxxvii; Nov. Org. Ren. iv. iii.

into zoology, which furnishes too many examples of them already. We have them compounded of Greek and Latin, as *Dendrofalco*, *Gymnocorvus*, *Monoculus*, *Arborophila*, *flavigaster*; Greek and French, as *Jacamaralecyon*, *Jacamerops*; and Greek and English, as *Bullockoides*, *Gilbertsocrinites*.

n. Names closely resembling other names already used.—By Rule 10 it was laid down that when a name is introduced which is identical with one previously used, the later one should be changed. Some authors have extended the same principle to cases where the later name, when correctly written, only approaches in form, without wholly coinciding with, the earlier. We do not, however, think it advisable to make this law imperative, first, because of the vast extent of our nomenclature, which renders it highly difficult to find a name which shall not bear more or less resemblance in sound to some other; and, secondly, because of the impossibility of fixing a limit to the degree of approximation beyond which such a law should cease to operate. We content ourselves, therefore, with putting forth this proposition merely as a recommendation to naturalists, in selecting generic names, to avoid such as too closely approximate words already adopted. So with respect to species, the judicious naturalist will aim at variety of designation, and will not, for example, call a species *virens* or *virescens* in a genus which already possesses a *viridis*.

o. Corrupted words.—In the construction of compound Latin words, there are certain grammatical rules which have been known and acted on for two thousand years, and which a naturalist is bound to acquaint himself with before he tries his skill in coining zoological terms. One of the chief of these rules is, that in compounding words all the radical or essential parts of the constituent members must be retained, and no change made except in the variable terminations. But several generic names have been lately introduced which run counter to this rule, and form most unsightly objects to all who are conversant with the spirit of the Latin language. A name made up of the first half of one word and the last half of another, is as deformed a monster in nomenclature as a Mermaid or a Centaur would be in zoology; yet we find examples in the names *Corcorax* (from *Corvus* and *Pyrhocorax*), *Cypsnagra* (from *Cypselus* and *Tanagra*), *Merularis* (*Merula* and *Synallaxis*), *Loxigilla* (*Loxia* and *Fringilla*), &c. In other cases, where the commencement of both the simple words is retained in the compound, a fault is still committed by cutting off too much of the radical and vital portions, as is the case in *Bucorvus* (from *Buceros* and *Corvus*), *Ninox* (*Nisus* and *Noc-tua*), &c.

p. Nonsense names.—Some authors having found difficulty in selecting generic names which have not been used before, have adopted the plan of coining words at random without any derivation or meaning whatever. The following are examples: *Viralva*, *Xema*, *Azeca*, *Assiminia*, *Quedius*, *Spisula*. To the same class we may refer anagrams of other generic names, as *Dacelo* and *Cedola* of *Alcedo*, *Zapornia* of *Porzana*, &c. Such verbal trifling as this is in very bad taste, and is especially calculated to bring the science into contempt. It finds no precedent in the Augustan age of Latin, but can be compared only to the puerile quibblings of the middle ages. It is contrary to the genius of all languages, which appear never to produce new words by spontaneous generation, but always to derive them from some other source, however distant or obscure. And it is peculiarly annoying to the etymologist, who, after seeking in vain through the vast storehouses of human language for the parentage of such words, discovers at last that he has been pursuing an *ignis fatuus*.

q. Names previously cancelled by the operation of § 6.—Some authors consider that when a name has been reduced to a synonym by the operations of the laws of priority, they are then at liberty to apply it at pleasure to any new group which may be in want of a name. We consider, however, that when a word has once been proposed in a given sense, and has afterwards sunk into a synonym, it is far better to lay it aside for ever than to run the risk of making confusion by re-issuing it with a new meaning attached.

r. Specific names raised into generic.—It has sometimes been the practice in subdividing an old genus to give to the lesser genera so formed, the names of their respective typical species. Our Rule 13 authorizes the forming a new generic name in such cases; but we further wish to state our objections to the practice altogether. Considering as we do that the original specific names should as far as possible be held sacred, both on the grounds of justice to their authors and of practical convenience to naturalists, we would strongly dissuade from the *further continuance* of a practice which is gratuitous in itself, and which involves the necessity of altering old names or making new ones.

We have now pointed out the principal rocks and shoals which lie in the path of the nomenclator; and it will be seen that the navigation through them is by no means easy. The task of constructing a language which shall supply the demands of scientific accuracy on the one hand, and of literary elegance on the other, is not to be inconsiderately undertaken by unqualified persons. Our nomenclature presents but too many flaws and inelegancies already, and as the stern law of priority forbids their removal, it follows that they must remain as monuments of the bad taste or bad scholarship of their authors to the latest ages in which zoology shall be studied.

[*Families to end in idæ, and Subfamilies in inæ.*]

The practice suggested in the following proposition has been adopted by many recent authors, and its simplicity and convenience is so great that we strongly recommend its universal use.

§ B. It is recommended that the assemblages of genera termed *families* should be uniformly named by adding the termination *idæ* to the name of the earliest known, or most typically characterized genus in them; and that their subdivisions, termed *subfamilies*, should be similarly constructed, with the termination *inæ*.

These words are formed by changing the last syllable of the genitive case into *idæ* or *inæ*, as *Strix*, *Strigis*, *Strigidæ*, *Buceros*, *Bucerotis*, *Bucerotidæ*, not *Strixidæ*, *Buceridæ*.

[*The authority for a species, exclusive of the genus, to be followed by a distinctive expression.*]

The systematic names of zoology being still far from that state of fixity which is the ultimate aim of the science, it is frequently necessary for correct indication to append to them the name of the person on whose authority they have been proposed. When the same person is authority both for the specific and generic name, the case is very simple; but when the specific name of one author is annexed to the generic name of another, some difficulty occurs. For example, the *Muscicapa crinita* of Linnæus belongs to the modern genus *Tyrannus* of Vieillot; but Swainson was the first to apply the specific name of Linnæus to the generic one of Vieillot. The question now arises, Whose authority is to be quoted for the name *Tyrannus crinitus*? The expression *Tyrannus crinitus*, Linn., would imply what is untrue, for Linnæus did not

use the term *Tyrannus*; and *Tyrannus crinitus*, Vieill., is equally incorrect, for Vieillot did not adopt the name *crinitus*. If we call it *Tyrannus crinitus*, Sw., it would imply that Swainson was the first to describe the species, and Linnæus would be robbed of his due credit. If we term it *Tyrannus*, Vieill., *crinitus*, Linn., we use a form which, though expressing the facts correctly, and therefore not without advantage in particular cases where great exactness is required, is yet too lengthy and inconvenient to be used with ease and rapidity. Of the three persons concerned with the construction of a binomial title in the case before us, we conceive that the author who *first* describes and names a species which forms the groundwork of later generalizations, possesses a higher claim to have his name recorded than he who afterwards defines a genus which is found to embrace that species, or who may be the mere accidental means of bringing the generic and specific names into contact. By giving the authority for the *specific* name in preference to all others, the inquirer is referred *directly* to the original description, habitat, &c., of the species, and is at the same time reminded of the date of its discovery; while genera, being less numerous than species, may be carried in the memory, or referred to in systematic works without the necessity of perpetually quoting their authorities. The most simple mode then for ordinary use seems to be, to append to the original authority for the species, when not applying to the genus also, some distinctive mark implying an exclusive reference to the *specific* name, as *Tyrannus crinitus* (Linn.), and to omit this expression when the same authority attaches to both genus and species, as *Ostrea edulis*, Linn. Therefore,

§ C. It is recommended that the authority for a specific name, *when not applying to the generic name also*, should be expressed thus, (Linn.), as *Tyrannus crinitus* (Linn.).

[*New genera and species to be defined amply and publicly.*]

A large proportion of the complicated mass of synonyms which has now become the opprobrium of zoology, has originated either from the slovenly and imperfect manner in which species and groups have been originally defined, or from their definitions having been inserted in obscure local publications which have never obtained an extensive circulation. Therefore, although under § 12 we have conceded that mere insertion in a printed book is sufficient for *publication*, yet we would strongly advise the authors of new groups always to give, in the first instance, a full and accurate definition of their characters, and to insert the same in such periodical or other works as are likely to obtain an immediate and extensive circulation. To state this briefly,

§ D. It is recommended that new genera or species be *amply* defined, published, and *extensively* circulated in the first instance.

[*The names to be given to subdivisions of genera to agree in gender with the original genus.*]

In order to preserve specific names as far as possible in an unaltered form, whatever may be the changes which the genera to which they are referred may undergo, it is desirable, when it can be done with propriety, to make the new subdivisions of genera agree *in gender* with the old groups from which they are formed. This recommendation does not, however, authorize the changing the gender or termination of a genus already established. In brief,

§ E. It is recommended that in subdividing an old genus in future, the

names given to the subdivisions should agree in gender with that of the original group.

[*Etymologies and types of new genera to be stated.*]

It is obvious that the names of genera would in general be far more carefully constructed, and their definitions would be rendered more exact, if authors would adopt the following suggestion:—

§ F. It is recommended that in defining new genera the etymology of the name should be always stated, and that one species should be invariably selected as a type or standard of reference.

In concluding this outline of a scheme for the rectification of zoological nomenclature, we have only to remark, that almost the whole of the propositions contained in it may be applied with equal correctness to the sister science of botany. We have preferred, however, in this essay to limit our views to zoology, both for the sake of rendering the question less complex, and because we conceive that the botanical nomenclature of the present day stands in much less need of distinct enactment than the zoological. The admirable rules laid down by Linnaeus, Smith, Decandolle, and other botanists (to which, no less than to the works of Fabricius, Illiger, Vigors, Swainson, and other zoologists, we have been much indebted in preparing the present document), have always exercised a beneficial influence over their disciples. Hence the language of botany has attained a more perfect and stable condition than that of zoology; and if this attempt at reformation may have the effect of advancing zoological nomenclature beyond its present backward and abnormal state, the wishes of its promoters will be fully attained.

Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field.—Concluding Report. By a Committee, consisting of Sir PHILIP DE M. GREY EGERTON, Bart., F.R.S., Professor T. H. HUXLEY, F.R.S. Reporter, WILLIAM MOLYNEUX, F.G.S.

THE coal-measures of North Staffordshire may be divided into four distinct groups, namely,

	feet.	feet.
The Lowest Measures from about	800	to 1000
The Lower Thick Measures „	2000	to 2500
The Upper Thick Measures „	1400	to 1800
The Upper Measures „	1000	to 1200

giving a total vertical thickness of from 5200 to 6500 feet.

The divisional formations of the lowest and lower thick measures in the Cheadle-field consist of shaly coarse and fine sandstones, which, although not proved by actual workings, would appear to be from 300 to 400 feet thick. The extension of these sandstones northwards is checked by an upthrow of Millstone-grits near Consall in the Churnet valley, and their place is occupied in the Knypersley and Biddulph districts of the extreme northern point by masses of black and brown shales and clayey laminated sandstones. The divisions of the other groups correspond with this in some respects, but they are less marked and massive. Each of these groups is characterized by the

presence of a distinct series of beds of coal and ironstone of greater or less value and persistency. The lowest measures contain seven seams of coal, three of which are worked for local use only, but the base is occupied by a most valuable bed of Hydrate, known as the Froghall ironstone. The lower thick measures contain all the best and thick coals, but only one band of ironstone (the Burnt Wood) of sufficient thickness or quality to be worked. The upper thick measures afford a remarkable contrast, as containing nearly all the workable bands of ironstone, while the upper measures contain thick masses of brick clays, with a few thin seams of coal, and but one or two bands of ironstone to which any attention has been paid.

It is probably a somewhat remarkable feature in connexion with these great divisions, that in no instance have the two middle groups been found to contain deposits showing an extended continuous water-action of a turbulent character; but in the upper part of the lowest measures, and the top beds of the upper measures occur rocks resembling in every particular those of the Millstone-grit. It may, however, be mentioned that instances have come under notice of the occurrence of large rounded quartz pebbles in shales and ironstones, lying near the base of the upper thick measures at Apedale; and in another case a large siliceous water-worn boulder, some pounds in weight, was met with at considerable depth near a fault in one of the pits of the Cheadle coal-field. It not unfrequently happens, however, that large masses, composed of fragments of plants, broken shells, and other organic remains, intermixed with subangular pieces of ironstone, coal, and shaly sandstones, cemented together by a hard paste, are met with in sinkings and workings in the neighbourhood of faults, but as a rule the enormous stratigraphical deposits of these fields evidence tranquillity of action extending over a very long period of time. This conclusion is borne out by the nature and condition of the organic remains imbedded in the shales and ironstones of the different measures, which are not only exceedingly numerous, but of a most remarkable and interesting order; and it may here be stated as evidence of the results of an extended palæontological inquiry, that before the commencement of a systematic course of research with reference to the subject, the known species of fish-remains were limited to the number of nine, with about the same number of shells, including those of a marine type then supposed to be confined to a single bed belonging to the lowest measures of the Churnet valley and its representative at Wetley Moor. The fish-remains are, however, now found to consist of from 35 to 40 genera, embracing upwards of 80 species, while the mollusca range out into upwards of 23 genera, represented by about 60 species; the marine forms extend at intervals upwards from the lowest to the upper thick measures, while the frequent occurrence of reptilian remains, and the vast number of the smaller crustaceans indicate the extended range and variety of the organic life of these fields during the period of their formation. These reptilian remains consist of single internal bones, with occasionally roughly ornamented external bones of the head. The range of these animals has been traced from the horizon of the Stinking Coal of the lowest beds, here and there up through the whole of the measures, to the chalky mine ironstone of the upper thick group. They are generally found in association with fish-remains, and appear to have been more numerous during the formation of the New Ironstone, the Knowles, and the Brown Mine ironstones of Kidsgrove, Fenton, Longton, Silverdale, and Apedale. They are, however, by no means confined to these localities, traces of them being found over the greater part of the area included in these fields, and also in direct association, both with shells referable

to marine conditions, and those assumed to be of brackish or freshwater origin.

Of all the forms of life met with in these fields the little *Cytheropsis* is the most numerous and persistent. It occurs in almost every distinct mineral deposit, and sometimes forms compact masses several inches in thickness, and entirely separated from all other organisms; at others it appears in association with *Microconchus* alone, or is mixed indiscriminately with fish and shells, or forms a thin layer or parting between beds of shale or ironstone, or the nucleus of ironstone nodules. It is, however, a fact of some importance in the question referable to the conditions under which certain coal and ironstone beds were deposited, that the little fossil has never been found in the fields under notice in direct association with shells known to be marine. A most interesting example of this severance occurs in the shales of the Stinking Coal at Windsend, in the Churnet valley. The lower parts of these shales immediately overlying the coal are remarkable for the immense number of *Aviculopectens* they contain in a compressed form, and associated with *Goniatites*, *Orthoceras*, and *Posidonia*. In various instances the same shale-bed has yielded *Cytheropsis* and *Beyrichia*, and occasionally *Anthracosia*; but these three latter fossils are always separated from the former. After repeated examinations, it has been ascertained that about two feet above the coal a well-defined division occurs in the form of a bone-bed, containing teeth, scales, coprolites, and other remains, with frequent concretionary nodules, distinctly compressed into the under surface of the shales. Above this line the *Aviculopecten* never passes, and in no instance have the *Cytheropsis* or *Anthracosia* been found below it; but each organic deposit is separated from the other as clearly and distinctly as could have been effected by the intervention of thick masses of strata.

With *Cytheropsis* are frequently found *Beyrichia*, *Microconchus*, and *Serpula*, but the latter genus is by no means so generally distributed. *Beyrichia* occurs in great numbers in the shales of the Cockshead ironstone at Adderley Green, in association with *Cytheropsis* and *Microconchus*; but *Serpula*, so far as has been proved, is confined to the shales of the Woodhead coal in the Cheadle field. Each of these forms, like *Cytheropsis*, is confined to the beds containing *Anthracosia*; they never pass into the marine horizons of either the upper or lowest measures.

Until the present year these fields were not known to contain any of the higher order of Crustacea; recently, however, a fragment of *Limulus* has been met with in a small nodule of the Hard Mine ironstone at Adderley Green; and more recently still a curious ironstone deposit, lying near the base of the lowest measures of the Churnet valley, has been found to contain Macruran remains of an interesting form associated with *Cytheropsis* and *Anthracoptera*. It is by no means unlikely that these latter organisms may be found to pass into the higher strata; but so far they appear to be confined to the particular bed in question.

The fish-remains of these fields are of an exceedingly interesting character, and in certain beds occur in great numbers, and in a most beautiful state of preservation. Many new forms have been met with, and individual specimens of well-known species occasionally come to hand, by which some important anatomical points have been satisfactorily established. The whole of these remains are now undergoing examination, and ere long a more complete knowledge of their specific character will be arrived at.

Of the Ganoid fishes, the most commonly distributed are the *Palæonisci*, which range throughout the whole of the four great divisions of the fields,

and pass downwards into the shales of the Millstone-grit and the grey iron-stone nodules of the Carboniferous shales. In the *Aviculopecten* shales of the Stinking Coal two or three at present undetermined species are imbedded, but rarely in a well-preserved condition. The species of this bed are intermixed with the marine shells, and appear to be different to those so largely distributed amongst the beds of the upper thick measures; and in no instance have they been found in this deposit to pass above the line of the bone-bed alluded to, where detached scales are largely intermixed with *Lingula* and other organisms in a fragmentary condition.

Towards the upper part of these lower beds a small species, tolerably perfect, is occasionally found imbedded in nodules of clay ironstone; but, generally speaking, between this point and the shales of the Ash Coal, the base of the upper thick measures, evidence of the existence of these fish seldom occurs, except in the form of detached scales, scattered over the face of the numerous intervening bone-beds. In the Ash-coal shales, however, they appear in a more perfect form, and attain their maximum development in the shales of the Deep Mine ironstone, 200 yards above it. This latter ironstone is at Longton, on the extreme western boundary of the proved measures, 1 foot 3 inches thick, and divided into four bands overlaid by a bed of black shale, hard, clean, and easily split into thin slabs. As an ichthyolitic depository it is one of the most interesting met with, and affords in addition some curious data referable to the range of animal life in one distinct horizon. This stone is worked at Longton, Fenton, Shelton, Berryhill, Sneyd Green, Golden-hill, and other places, but not always under the same name. The Longton bed is opened at two points communicating with each other, and from the shales of these two workings have been collected, in a remarkable state of preservation, specimens of eighteen genera, and about twenty-six species of fish. One new genus, under the name of *Cycloptychius*, occurs in great numbers and the most perfect condition; but beyond the limits of the two pits at Longton it has never as yet been known to pass; and in each direction from this point, where the stone has been worked, the whole of its organic remains die gradually out to a few detached scales and isolated teeth. The restriction of the *Palæonisci* of this deposit to a definite range would appear to indicate the prevalence of either deep or shallow water along this particular line; but it is in the character of its organic contents that this peculiarity is the more observable; the stone itself, where it has been pierced, although showing a tendency to thin out towards its eastern outcrop, retains over the greater part of the field a tolerably uniform thickness and character.

Of *Cœlacanthus* there are two species, *C. lepturus* and *C. granulatus*, the former being the more common, and of greater range. Detached scales are met with in the Hydrate shales, and here and there in the fossiliferous beds of the lowest measures, including the Stinking Coal shales. In the Woodhead coal-shale of the lower thick measures, *C. lepturus* is occasionally found in a fair state of preservation, and also in the nodular grey ironstones intermixed with the grey shales above it. More frequently, however, it occurs as detached scales; and in this form, wherever *Palæoniscus* is detected, both *Cœlacanthus* and *Platysomus* are generally in association with it. The Deep Mine ironstone contains numerous fine specimens, and it not unfrequently occurs in the Cockshead, Knowles, and Brown Mine ironstones and shales.

Platysomus, of which there are two species, has a somewhat similar range; but in certain deposits, in different localities, each species appears to be a characteristic feature.

Many of the coal and ironstone beds are either of local extent, or evidence a variation of condition of deposit within a limited area, and consequently the measures of one district are no sure guides in engineering to those of another. This more frequently happens in the upper thick beds with the ironstone group, and it is found that this diversity in the character of the mineral deposits is partaken of in a somewhat similar degree by the forms of life directly associated with them. Taking the Longton and Fenton beds as one example, the Deep Mine shales show the predominating form to be *Palæoniscus*, the Knowles ironstone *Platysomus*, and the New Ironstone *Megalichthys*. At Silverdale and Apedale *Palæoniscus* is rare, while the Brown Mine teems as it were with *Platysomi*. Passing to the Kidsgrove district, the Brown Mine becomes the New Mine, and *Platysomus* gives place to *Rhizodopsis*, and passing downwards to the Woodhead coal, *Cœlacanthus* appears as the characteristic fossil of its bed. The life-zone, as it were, of each of these deposits also varies. In the case of the Deep Mine, it is confined to a few inches of black shale immediately overlying the stone, and in no known instance passing into the mineral itself. In the Knowles ironstone shales the same conditions are observable; but the life-zone extends downwards into the stone, fine specimens of *Rhizodus*, *Cœlacanthus*, *Acanthodes*, and *Megalichthys* being of frequent occurrence in the upper division of the bed. The Brown Mine of Silverdale and the New Mine of Kidsgrove present parallel conditions; but in the Brown Mine of the latter district the shales form only the matrix of its interesting organisms. The beds of ironstone and coal enumerated—the Woodhead and Ash coals, and the Cockshead, Knowles, Deep Mine, Brown, and New Mine ironstones—appear to be the great fish-zones of these fields; but it may be accepted that the whole of the mineral beds contain the remains of either fish or shells, generally both. These remains, as previously stated, are rare in certain localities; but no bed has hitherto been found totally unfossiliferous over the whole of its proved area. It is also worthy of note, that in almost all, if not every case, the divisional line between each seam of coal and band of ironstone and their associated shales or bass, consists of a thin film, as it were, of detached scales and teeth of fishes or compressed mollusks, showing in a simple but conclusive manner that whatever may have been the condition under which each bed of coal was formed, it was immediately after its formation covered by water containing the ordinary forms of life of that period, and which by its agency were spread over the surface of each coal-bed before becoming charged with the mud now forming its superimposed shales. Frequently the ironstones are immediately overlain by thin beds of coal; and in the case of the New Mine at Kidsgrove, this coal is largely intermixed with fragments of *Gyracanthus*, *Megalichthys*, and other fish-remains; but this is the only instance in the field in which such fossils have been detected within the body of coal itself; and in this case the coal which forms a parting between two bands of stone is not of the ordinary character of coal-deposits, but evidently the aggregated parts of an older bed brought from another point, and redeposited by aqueous agency.

In addition to the Ganoid fishes enumerated, *Acanthodes*, *Acrolepis*, *Gyrolepis*, *Pygopterus*, *Diplopterus*, and *Megalichthys* are forms more or less familiar to these beds, most being represented by two or more species, which appear here and there at intervals throughout the entire vertical strata. *Megalichthys Hibberti* is by far the most common form; but hitherto no perfect specimen has been met with. The New Ironstone of Fenton Park, the Gubbin ironstone shale of Shelton, and the Chalky Mine ironstone of

Silverdale, have yielded fine examples of this fish—in the latter case a fragment of a jaw 16 inches in length. With this fish are frequently associated in the New and Knowles ironstones large jaws referred to *Rhizodus*, and others as yet not satisfactorily determined.

The small cycloidal-scaled fish assigned to *Rhizodopsis* is also of common occurrence, and with it are occasionally found large circular scales, with concentric and radiating lines of ornamentation. *Acanthodes* is also of wide range, being more abundant in nodules of the Cockshead ironstone, and in the Knowles and Deep Mine ironstone shales, which also contain *Gyrolepis* and *Pygopterus*. *Strepsodus*, a long somewhat curved tooth with parallel lines, also ranges from the Stinking Coal to the upper beds, but always in detached forms. *Amblypterus* so far appears to be extremely rare in these fields.

The Placoid order of fishes is freely represented, and possesses an equally determinate range with the ganoid forms of the field. *Pleuracanthus*, or the old *Diplodus gibbosus*, occurs in thousands in the New Ironstone at Fenton Park, making its first appearance in the shales of the Stinking Coal, and ranging upwards to the Red Shag ironstone of the upper beds. The spine described as *Pleuracanthus*, is frequently found associated with the teeth and dermal covering of the fish, in a manner which confirms the now received opinion of their common origin. *Pleuracanthus minutus* is not so common, but it has a wide and general range, and another species is not unfrequent in the New Ironstone of Fenton Park, but it is rarely found to pass from this horizon. Of the large dorsal spines, *Ctenacanthus*, the species *hybodontoides* is the most familiar, but it is seldom found out of the New Ironstone, Deep Mine, Knowles and Brown Mine shales. *Gyracanthus formosus* is of far wider distribution, being found in twelve different beds of the lower and upper thick measures. *G. tuberculatus* is frequently associated with it, but it is of less vertical range. *Orthacanthus cylindricus* is also confined to the upper part of the thick coal and the lower part of the ironstone groups, but, like *Ctenacanthus* and *Gyracanthus*, the finest specimens are obtained from the New Ironstone of Fenton Park. The fossil known as *Onchus* is remarkably persistent in its distribution, being plentiful in the Stinking and Woodhead coal-shales, and in nearly the whole of the coal and ironstone beds of the succeeding measures. A form resembling *Leptacanthus*, and others with double or single rows of curious hooked teeth, are not unfrequently met with, especially in the New Ironstone, which appears to have been the great life-centre of the singular animals to whom those defensive weapons belonged.

The remainder of the Placoid fish consist of the genera *Cladodus*, *Petalodus*, *Ctenodus*, *Orodus*, *Ctenoptychius*, *Archodus*, *Pæcilodus*, *Helodus*, some forms resembling *Cochliodus*, a small tooth with numerous branching cusps, and others as yet undetermined. *Ctenodus* appears to be limited to the New, Brown Mine, Knowles, and Black-band ironstones, and is of somewhat rare occurrence. *Petalodus* is of similar range, and *Cladodus* extends to the Woodhead coals, and is frequently found in groups on slabs of the Knowles ironstone and Ash-coal shales. *Orodus* is confined to the Stinking Coal of the lowest measures, and also another form of an exceedingly interesting character, of which but two specimens have been detected. *Ctenoptychius* is represented by three or four species, of which *apicalis* is the most common, the New Ironstone containing remarkably fine examples. *Archodus* is a rare form, and appears to be confined to the latter bed. To *Helodus* no limit can well be given, it being met with in almost all the beds, and in the Knowles is frequently of large size. The tooth resembling *Cochliodus* is rare, and has

not been met with in other beds than the Stinking Coal, and in the stony 8-foot ironstone at Kids Grove. *Pecilodus* is a common form in the Cockshead ironstone shales, and has a tolerably wide range from the Stinking Coal upwards. The little tooth with numerous cusps is confined to the New and Deep Mine ironstones, but is frequent in the former bed. In addition to these, there is a fine lancet-shaped tooth rarely found in the Deep Mine, Wood's Mine, New, Bassey Mine, and Gubbin ironstones, to which at present no name has been assigned.

The Mollusca of these fields may be divided into three distinct groups—the *Aviculopecten* and *Goniatite* group of the lowest measures, the *Spirifer* and *Discina* group of the middle, and the *Anthracosia* of the entire fields. The *Aviculopecten* of the lowest measures is represented simply by the species *papyraceus*, and is confined to two horizons, that of the Stinking Coal about 100 feet above the Millstone-grit, and a lean grey ironstone about the same distance above the Stinking Coal. In the latter bed it is associated with *Goniatites*, *Posidonia*, *Orthoceras*, and *Lingula*, each of which are invariably found to occupy different and successive levels in the deposits to which they are confined.

Immediately upon the coal, which is strongly sulphureous, comes a bed of *Aviculopectens*, from 6 to 8 inches thick; this is succeeded by a layer of *Goniatites* of similar thickness; then *Posidonia* and *Orthoceras*; the black shales containing fish, and at the top of all comes *Lingula* mixed with scales of *Pulmoniscus*. The *Aviculopecten*, *Goniatites*, *Posidonia*, and *Orthoceras* bands are generally dovetailed, as it were, into each other, but each contains nevertheless its characteristic features. *Lingula* is, however, always sharply cut off from them and confined to one definite line on the top of the shales immediately below the bone-bed which separates these fossils from the on-coming *Cytheropsis* and *Anthracosia*. The *Aviculopecten*-bed is of great areal extent, and retains a remarkable degree of uniformity in whatever district it is found, and in more than one important case the existence of certain valuable mineral deposits have been determined by its presence alone. In the Goldsitch-moss basin, 10 miles direct north from Ipstones, it forms one of the coals worked there under the name of the Thin Seam; at Wetley Moor it is represented by the Four-foot coal, at Biddulph by the Biddulph Moor coal, and in each locality it contains its characteristic tranquilly deposited fossils, in equal numbers and corresponding conditions.

The other *Aviculopecten*-bed is a thin grey laminated ironstone about 100 feet above the Stinking Coal, and hitherto has not been detected beyond the limits of the Churnet valley. Its fossils are in a fine state of preservation, but so far it has not been found to contain other remains than *Aviculopecten papyraceus* and *Posidonia*.

The base of the lowest measures of the Churnet valley is a clayey marl, which reposes directly upon the upper beds of the Millstone-grit, and varies in thickness from a thin film to 15 feet. This is succeeded by the well-known Hydrate, a most curious and remarkable deposit, varying from an inch to 2 feet 6 inches. The shales in contact with this ore, and the stone itself in certain localities, contain great numbers of *Anthracosia acuta*—a form of life which takes precedence of all others in the history of the period represented by these rocks. Between this bed and the Stinking Coal the only recognizable fossils are scanty remains of fishes; but here, as before stated, *Anthracosia* again comes in, and again gives place to the *Aviculopecten* of the laminated ironstone. In the succeeding clay ironstone nodules it is accompanied by other species, but from this point up to the marine bed

opened up at Hawley's sinkings, there are no known indications of the introduction of other forms of life than those of which this genus is the type.

In the Woodhead coal-shales of the Cheadle field, and other basement beds of the lower thick measures at Norton and Bucknall, *Anthracomya* and *Anthracoptera* are found in association with *Anthracosia*, the latter being represented by the species *subconstricta*, *robusta*, *ovalis*, and others; *Anthracomya* by *Adamsii*, and *Anthracoptera* by two new species, and others. In the Bullhurst coal and its succeeding shales these bivalves frequently occur in immense numbers, especially in the Cockshead ironstone, the Hard Mine, Little Mine, and the various Banbury coals of the Silverdale and Kidsgrove districts, and in the Bassey Mine, Gutter Mine, Cannel Mine, and Black-band ironstones of the upper thick measures. It is however remarkable that, where they are unusually abundant, fish-remains become scarce and fragmentary; in fact none of the deposits which retain their original condition afford conclusive evidence of other than the occasional commingling of these vertebrate and invertebrate animals in the waters of the period, and it is only in the aggregated bone-beds that their remains are associated in anything like equal proportions.

In many cases the bone-beds covering the surface of coal pass into thick irregularly-deposited masses of shells, which by their persistency become valuable guides in mining operations. Not unfrequently, however, they are confined to a definite horizon, the shales above them being destitute of other remains than those of plants matted together and imperfectly preserved. As a rule the coal-beds are of greater extent and of a more uniform character than ironstone deposits. In the upper measures both are usually but slightly divided, and, generally speaking, where the ironstone thickens the coal becomes inferior. The Longton ironstone-beds in many instances die out altogether, or are but obscurely represented in the Silverdale and the more easterly districts, and this is in fact the case with the coal in many cases. The position of the shells varies according to the character of their matrix; in some instances they appear *in situ*, smoothly laid out, and rising layer upon layer to the thickness of several feet. In this form they are generally compressed, but in many others, such as the Moss coals, Hard Mine, and Cockshead ironstone-shales, they retain their original shape.

Until within the last two or three years there was no published evidence to show that the generally received opinion of the restriction of marine fossils to the lower measures of the British coal-fields was incorrect; but some sinkings at Longton in the spring of 1863 revealed the existence of a series of such remains in the shales of a thin unworked coal called the Bay Coal, situated towards the base of the upper thick measures. These remains consisted of *Aviculopecten*, *Goniatites*, *Lingula*, *Orthoceras*, *Spirifer*, *Otenodonta*, *Macrocheilus*, *Naticopsis*, *Nautilus*, *Loxonema*, and *Discina*. The discovery of *Lingula*, which at the time was the only form met with, was announced in the Report of your Committee read at the Meeting at Newcastle, and the occurrence of the additional forms was also noticed in their Report read at Bath last year. It has, however, been subsequently found that, about eight years ago, *Discinae* were discovered in nodules of the Priors-field ironstone at Fenton Park.

From the Bay Coal not being a workable seam, its extension can only be proved by sinkings in other parts of the field, where it will have to be looked for under different names and position, no other section appearing to agree with the one at Longton. The Priors-field ironstone, which lies below the Bay Mine, also yielded at the same sinkings *Lingulae* and *Discinae*, but,

except in one instance, of the association of the young of *Discina* with *Anthracopectera*, none of the other forms were found in direct contact with them. *Discinæ* have recently been met with at Kidsgrove in grey ironstone nodules, which would appear to be representatives of the Longton Priors-field bed.

The Bay Coal fossils appear to be confined to a thin stratum of shale, containing grey flattish nodules of lean ironstone overlying the coal. The *Lingulæ* were never known to pass into the ironstone, but appeared to lie near the top of the shales in association with *Discinæ*. Below these come *Orthoceras*, *Spirifer*, and the others, and the nodules were generally taken up with *Aviculopecten*, *Spirifer*, and *Productus*. Immediately above these shales came another nodular bed of ironstone and thick shales, and these were the depositories of several species of *Anthracosia* with *Cytheropsis*; but here, as in the Stinking Coal, the line of demarcation was in no case passed by either of the forms above or below it. The Priors-field group appears to be equally defined, *Anthracopectera* and *Cytheropsis* overlying the *Lingulæ* and *Discinæ*. This isolation of *Lingulæ* from all other than *Discinæ* is a somewhat curious fact, but the cases cited are not the only ones which have come under notice. It occurs in the shales of a coal worked on the western flank of Axedge, and referred to the middle beds of the Millstone-grit.

In June and July of the present year a bed of greyish shale, lying a few feet above the Gin Mine coal, belonging to the upper part of the lower thick measures, was sunk through on the hill which divides Longton from Adderley Green. These shales far surpass the Bay Mine in the number and variety of their organic contents. They contain *Productus*, *Chonetes*, *Lingula*, *Aviculopecten*, *Ctenodonta*, *Avinus*, *Naticopsis*, *Chemnitzia*, *Loxonema*, *Platyschisma*, *Pleuronomaria*, *Discites*, *Goniatites*, *Nautilus*, *Orthoceras*, and others, most of them being represented by two or more species, some of which are new.

More than one of these forms are common in the carboniferous rocks of Scotland, and others are found abundantly in the Millstone-grits of Staffordshire. It is an interesting feature in these deposits that they contain *Productus*, *Spirifer*, and *Nautilus*, which are absent in the lowest measures of these fields. The occurrence of this bed is important as showing that the two great divisions of the upper and lower thick measures are at widely separated intervals, interlined by deposits which point to the sudden cessation of one order of natural operations, and the introduction of another, which obtained for a comparatively short period and then passed away, to be repeated long after in two distinct but less important forms, but still equally clear and equally conclusive. Whether there are other instances of these isolated marine conditions in the middle measures, or whether they stretch into the upper strata of the coal-field, a careful examination of beds passed through in future sinkings will alone determine.

On the extreme western outcrop of the coal strata at Longton a bed of limestone, supposed to be of freshwater origin, overlies the Bassey Mine ironstone at a distance of about 30 feet. Recent sinkings on the Longton Hall estate have revealed a second band of limestone 30 feet below the other, and like it divided into three beds by thin partings of clayey shale. The upper bed has long been known, but in no other instance has the second bed been met with, although there are several pits within the space of 300 yards. Far above this, however, a little below the base of the brick clays of the upper measures, a third, if not a fourth bed of similar limestone has been exposed at distant points, in each of which the fossil contents specifically agree. The lower beds are the more fossiliferous, and include great numbers of *Cytheropsis*, *Microconchus*, *Anthracosia Phillipsii*, with scales and teeth of

Cœlacanthus, *Platysomus*, *Rhizodopsis*, *Megalichthys*, and *Pleuracanthus*. *Anthracosia Phillipsii* is also remarkably abundant in the Bassey Mine and the Gutter Mine ironstones, the latter being composed almost wholly of compressed forms of this shell. The Black-band ironstone of Apedale is also extremely rich in similar species, and contains, in addition, *Sanguinolites*, with thick masses of *Cytheropsis*. *Anthracosia Phillipsii* appear to be the characteristic shell of these upper thick measures, occurring abundantly in the Cannel Mine and other beds worked in different localities, until it dies out in the valueless coal-seams which interline the arenaceous shales of the upper beds of Hartshill and Newcastle-under-Lyne.

It may be stated in conclusion that, in drawing up their Report, your Committee have confined themselves as much as possible to the more striking particulars of the inquiry. The subject is in itself of too voluminous a character for detailed treatment, and a great amount of interesting matter has been necessarily omitted. Much of this, however, will be supplied by carefully prepared lists of the whole of the fossils found in the various measures of the field, which will be arranged in stratigraphical order for future publication.

Report of the Committee appointed to explore the Marine Fauna and Flora of the South Coast of Devon and Cornwall.—No. 1. *Consisting of* J. GWYN JEFFREYS, F.R.S., REV. THOMAS HINCKS, JONATHAN COUCH, F.L.S., CHARLES STEWART, J. BROOKING ROWE, F.L.S., and J. RALFS, F.L.S. *Reporter*, C. SPENCE BATE, F.R.S. &c.

IN presenting the first Report of the results of the Committee formed for the purpose of dredging the southern coast of Devon and Cornwall, we think it undesirable to repeat the full list of animals as recorded in our Dredging Tables. We shall therefore mention only those species that are either new or rare, or exhibit some especial interest from observation of some hitherto unrecorded peculiarity of habit or structure. We cannot communicate the result of our labours without expressing our appreciation of the service that we received from Her Majesty's Gunner's Ship 'Cambridge.' Capt. Ewart, C.B., having kindly offered any assistance that we might require on the water, we were not slow to avail ourselves of the ship's launch and crew for the purpose of dredging, and were on those occasions accompanied by Dr. Forbes of the 'Cambridge,' a gentleman known to science for an excellent memoir on the History and Topography of Vancouver's Island.

PISCES.

In reporting on the Fish, Mr. Couch says that although our success in this quarter has not been very abundant, still however our labour has not been without some considerable amount of success.

Among the ordinary inhabitants of our coast we scarcely expected to have found the *Twait shad*, so near the bottom, in rather deep water, as to be taken in the trawl; we were also enabled to obtain a knowledge of the ordinary food of the *Mcgrim* or scaldfish, *P. arnoglossus*, of which the examples were numerous: small specimens of *Galathee* were in their stomach.

We were also fortunate enough to obtain a specimen of the Filefish, *Balistes capriscaus*, the second on record as having been taken in England, and offering in some respects a different appearance from the figures given of

it by Willughby and Yarrell; but the particulars of this difference, as well as the way in which it was caught, it would be tedious to give now, and Mr. Couch reserves them for his work on our native fishes that is now publishing. Also an account of another fish which we have obtained within a few days (Aug. 18th), and now report for the first time as a visitor to our coasts. This is the Short-finned Tunny, *Thynnus brachyterus* of Cuvier; an example of which we procured from Mevagissey, and a second from Polperro; Mr. Couch has made drawings of both these rare fish.

We also obtained from the trawl a specimen of *Myliobates aquilæ*, or Eagle Ray.

MOLLUSCA.

Among the Mollusca of more or less interest the following are recorded:—

An exceedingly fine specimen of *Octopus vulgaris*, as well as of *Loligo media*, *Sepia elegans*, and *S. officinalis*. Also the ova of a *Sepia*, containing the rudimentary shell, apparently differing from those of *S. officinalis*, but of what species we have not yet been enabled to determine.

A beautiful specimen of *Idalia elegans*, far more brightly rose-coloured than the figure given by Messrs. Alder and Hancock, from which our specimen also differed in the posterior extremity of the foot, terminating in three instead of a single point.

We might also mention a specimen of *Avicula* being taken about half an inch longer than the greatest length ascribed to it by Prof. Edward Forbes.

CRUSTACEA.

The first species of crab to which we shall allude is that of *Achæus cranchii*, spoken of by Bell as being rare; two specimens only being recorded, one from Falmouth, the other from the South of Ireland.

Certainly this little crab is by no means uncommon off the coast of South Devon, in depth from six to twenty fathoms. This circumstance enables us to state that the second and third pairs of pereopoda are not drawn of sufficient length in proportion to the two posterior, in both Prof. Bell's and Dr. Leach's figures of the species.

Among the specimens that we dredged, we took two from six fathoms of water near the Knapbury, that possibly may be a second species. Our attention was first drawn to the circumstance from observing a peculiarity in its habits from that of the known species, which is that it covers itself with weed as we know is done by those of the genus *Pisa*.

In *Pisa* this is no accidental occurrence, since all the spines are sharp-pointed and curved; and my friend Mr. Whitford has informed me that he has observed specimens in his aquarium which soon after having cast their exuviae, pick up with the claws pieces of weed and place them on the spine.

In *Achæus cranchii* the spines are straight, a circumstance that gives the animal generally a hairy appearance. In the second form the spines are not visible to unassisted observation, and the legs of the animal look smooth and free from hairs, but a nearer and closer inspection shows that the spines are all hooked as in *Pisa*. The form of the eye somewhat varies also; but whether these are sufficient to ground a specific distinction of the two animals, we have not quite determined, particularly as we have observed among the mass of straight hairs in *A. cranchii* a few hooked ones also.

Of the interesting genus of soldier-crabs, *Pagurus*, we have taken six or seven species, viz.—

P. bernhardus.
prideauxii.
cuanensis.

P. hyndmanni.
dillwynii.

P. lævis.
ulidianus.

Of the last species we have some doubt, as Mr. Bell remarks, it is extremely like the young of *P. bernhardus*, and certainly until we can capture a specimen bearing ova we are much inclined to believe that it is so.

We are glad to be able to record *P. dillwynii* from the south coast of Devon. It is now about fifteen years since the first and only specimen was taken on the coast of South Wales. No other naturalist appears to have fallen in with it, and we found it necessary to take an occasional look at the original specimen to assure ourselves that we had not committed a mistake in considering it to be distinct.

A few weeks since, seeing a woman shrimping on the sandy beach at Teignmouth, we requested to have a look into her net, and among the common shrimp we saw to our great pleasure numerous specimens of *P. dillwynii*; after purchasing her entire stock we hastened to the beach, and with the incoming tide took numerous specimens which we kept alive for a short time. This, the prettiest of all the pretty genus, has the habit of burrowing in the sand, and it is probably to this circumstance that it has not been met with before; but, curious enough, we have since taken it with the dredge in about four fathoms of water in Bigberry Bay, and again one specimen in six fathoms as near to Plymouth as the mouth of the river Yealme.

An interesting point in the history of this genus we have been enabled to make out relative to the development of the young. The end of April or the beginning of May is the period when the young appear to be most abundant. Early in June we were enabled to capture many specimens of the young animal in various degrees of progressive development, a circumstance that has enabled us to determine that the species *Glaucothoe peronii*, described by Prof. Milne-Edwards in the *Annales des Sc. Nat.* for March 1830, is none other than an immature stage of the genus. At this period the little creature swims freely in the ocean, until obliged by increasing age to take refuge in a shell, when he settles down and becomes a hermit crab.

Of the genus *Palinurus* we would desire to point out a curious and interesting structural condition of the inferior antennæ. In all macrourous decapods the inferior pair of antennæ is furnished with a lateral scale, or articulated process. This is invariably situated at the extremity of the third joint of the peduncle; now in *Palinurus* this scale or squamiferous process is incorporated with the walls of the peduncle, the third and fourth joints being fixed together, and the squamiferous process exists in form only as a figure impressed against the sides of the antennæ.

In the elaborate memoir of Prof. Kinahan on the genus *Crangon*, we think that he has erroneously figured the common shrimp, or that the common shrimp of the Irish, differs from those of the English shores. The small and delicate second pair of pereopoda that Mr. Bell describes as being "nearly as large as the third," and figures rather shorter than the first, Dr. Kinahan makes as long again as the first pair. Prof. Kinahan's figure is also more slender than that of our edible shrimp; neither can we see the desirability or convenience of the generic separation which he has made between those having the second pair of pereopoda short from those that have them a little longer. This being only variation in degree, and not structurally important, we consider as being only of specific and not generic value.

Among the prawns we are enabled to add a new genus to the British fauna, namely, *Caradina* of Prof. Milne-Edwards. In making this interesting addition, we must remark that it is one of name only, since it is, we believe, the same that Dr. Leach described under the name of *Hippolyte varians*, which has remained so long misinterpreted. We have occasionally

taken this species when dredging in Plymouth Sound, but never so abundantly as of late.

We have previously observed the peculiar robust looking second pair of pereopoda, but it was not until recently we discovered that it had the peculiar structural formation peculiar to the genus *Caradina*, in which the propodos articulates with the carpus, not at the centre, but at the infero-anterior angle, and thus appears as a partially dislocated joint.

There is a second specimen that appears to me to be specifically distinct from the preceding; it is more slender, and has the rostrum long and slight. The teeth are two above, the one at the base flanked by a lateral tooth on each side, and one near the apical extremity; on the under side there is a tooth immediately under the anterior upper tooth, and a second posterior to it: to this species we provisionally give the name of *Caradina tenuis*.

Among the sessile-eyed Crustacea we have added to our local fauna *Monoculodes stimpsoni* and *Amphithoë albomaculata*; of the latter we took but a single specimen, and remarked the similitude of its colouring to that of half-grown specimens of *Amphithoë rubicaudata*.

Considerable numbers of *Tanaïs* have been captured deeply inserted in the crevices of the slate rocks of the coast, a habitat that is also favourable for the residence of *Anceus*, a genus whose sexes have long been placed in separate genera. These we have been enabled to work out with great care, a circumstance that enables us to support some of the views of M. Hesse, and unite the two supposed genera as the male and female of one.

We have only to add the peculiar circumstance of our having captured *Chondrocantha zeia* attached parasitically to a specimen of *Synapta*.

ANNELIDA.

Among the *Annelida*, Mr. J. Brooking Rowe remarks that the following have been made out, but we have many specimens as yet undetermined.

Gen. <i>Serpentaria</i> .	Gen. <i>Psamathe</i> .
S. fusca.	P. fusca.
Gen. <i>Pontobdella</i> .	Gen. <i>Glycera</i> .
P. muricata.	Two species not yet determined.
P. verrucata.	Gen. <i>Cirratulus</i> .
Gen. <i>Tomopteris</i> .	C. borealis.
T. oniseiformis.	C. tentaculatus?
Gen. <i>Aphrodita</i> .	Gen. <i>Chaetopteris</i> .
A. aculeata.	C. insignis.
A. hystrix.	Gen. <i>Arenicola</i>
Gen. <i>Lepidonotus</i> .	A. piscatorum.
L. squamatus.	A. ecaudata.
Gen. <i>Sigalion</i> .	Gen. <i>Terrebella</i> .
S. boa.	Three species, which appear to
Gen. <i>Eunice</i> .	differ from any previously
E. sanguinea.	described as British.
Gen. <i>Northia</i> .	Gen. <i>Pectinaria</i> .
N. tubicola.	P. belgica.
N. conchylega?	Gen. <i>Sabella</i> .
Gen. <i>Nereis</i> .	S. penicillus.
N. brevimana?	S. savignii.
N. pelagica.	Gen. <i>Serpula</i> .
Gen. <i>Heteronereis</i> .	S. vermicularis.
H. longissima?	

ALCYONIDIADÆ.

Among the Alcyonidiadæ we have taken two species, in addition to *gelatinosum*, to which we do not find any reference in the first edition of Dr. Johnston's 'Natural History of British Zoophytes.' One of these resembles so much the coral *Eschara cornu-cervi*, that but for its soft texture and flexibility it might be compared to it. The other resembles a short club, almost an oval mallet, on the top of a slender footstalk. Figures of these have been taken.

ECHINODERMATA.

Amongst the Echinodermata may be mentioned *Echinus flemingii*, *Spatangus purpureus*, *Porania pulvillus* (*Goniaster templetoni* of Forbes), and *Palmipes placenta*: these specimens are often brought in by the trawlers, but sometimes a maund containing little else than the *Palmipes* is procured at one time, the others being rather rare. Amongst these and their more common associates we have on three occasions found a specimen of *Luidia savignii* about eight inches in the greater diameter, and twice a single ray of what we believe to be *Luidia sarsii*. It is seven inches long, more abruptly tapering than in the other species; its upper surface orange, with purplish-brown spots at the base of the spines of the paxillæ; in all other respects it answers the description given of the species by the Rev. A. M. Norman in his paper on the genera and species of British Echinodermata published in the 'Annals of Natural History.' This is, we believe, the first notice of a western locality for this interesting animal, which must have been fifteen inches in its greater diameter. On the inner side of the eastern end of the Breakwater, where grey mud has collected, six specimens of *Amphiura filiformis*, remarkable for its pickaxe-shaped spines, occurred in one haul of the dredge. This species also has not been noticed here before, the Durham and Northumberland coasts being the only English localities yet given. *Antedon rosaceus* is common in the Sound, where it is found principally on the rocks that project from the mud and rubble of the bottom; of late years they have greatly extended their colonies, owing probably to the injured specimens having been thrown overboard whilst the boat was moving to a different spot.

Ophiothrix fragilis (*Ophiocoma rosula*, Forbes) is common everywhere, its colours being most varied. We only mention it here to point out an important modification of the spines nearest the cirrhi, they being converted into hooks of two or three points, which must greatly assist them in maintaining their hold of the rocks on which they live; and more especially must these be useful in the young star-fish, whose life is for some time spent on sponges, from which it is, indeed, often difficult to remove them without injury. *Ophiocoma nigra* often occurs mixed with the last species, but is never so numerous. Specimens of *Holothuria nigra* are sometimes dredged, and *Oenus brunneus* is not uncommon in the Sound. We have also obtained *Pentacta hyndmanni* deeply wedged into the holes made by *Saviceva* in the rocks outside the Breakwater. *Sipunculus bernhardus*, *Thalassema neptuni*, and one example of *Syrinx nulus* have also been found here. From Polperro we have received a specimen of *Synapta*, but was unable to determine its species as the preservative fluid had destroyed its anchors and plates. Some years since one was also obtained in the Sound, but was not, I believe, preserved.

Before concluding this Report it may be interesting to briefly describe a curious, and probably unique abnormal growth found on the oral surface of an *Echinus sphaera*. On opening the shell the inner surface of this part appeared as if sand or some foreign substance had got under the perisoma, but on closer examination this was found to be owing to a growth from the

shell, principally occurring at the lines of junction of its separate plates. It was in the form of short columns and fungoid masses, on the tops of which the perisoma rested : this outgrowth presented, on microscopical examination, a calcareous network, finer and more loose than the other portions of the shell. The Echinus was not altered in form externally, but it seems probable that such a growth, by uniting the plates composing the shell and so preventing the increase at that part, should ultimately cause some distortion.

Interim Report of the Committee on the Resistance of Water to Floating and Immersed Bodies. By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.S., JOHN SCOTT RUSSELL, C.E., F.R.S., JAMES R. NAPIER, Marine Engineer, and WILLIAM FROUDE, C.E.

1. The following Interim Report describes the experiments made by the Committee up to the day before the commencement of the present Meeting. Those experiments are still in active progress.

2. The Committee held several meetings in the course of the past winter and spring, and agreed to a programme of experiments of which the following is a summary.

3. Two models to be made of painted wood, designated respectively as A and B.

The models to be ship-shape, and each of them to consist of two equal and similar halves joined together at the middle water-line.

Elements of Models.

	A.	B.
Length	4·000 feet	4·000 feet
Breadth.....	0·571 foot	0·571 foot
Total depth	0·571 „	0·364 „
Form of Midship Section.	Circle.	Ellipse.
Area of Midship Section	0·256 sq. feet	 0·163
Form of Water-lines of fore-body.....	Harmonic curves.	
Form of Water-lines of after-body	Trochoids.	

Stem and stern-post vertical straight lines.

Length of fore-body : Length of after-body :: 3 : 2 3 : 2

Mean girth 1·45 foot.. 1 foot.

Model A to be in two parts joined at the circular midship section, so that by turning the after-body through a right angle about a longitudinal axis the water-lines can be converted into buttock-lines, and *vice versa*.

4. Experiments to be made according to the method formerly put in practice by Mr. Scott Russell, in which the uniformity of the propelling force is maintained by means of a regulating weight hanging from a pulley under which the hauling cord passes ; the model to be guided in a straight course by means of a stretched wire.

5. Those experiments to be made principally at speeds not exceeding the natural speed of the wave corresponding to the length of the model, viz., about two knots per hour ; but a few experiments may be made at higher speeds.

6. The experiments to be made on each model under two circumstances, viz., with the model immersed as nearly as may be to the middle water-line, and with the model totally immersed.

7. The programme of experiments having been thus drawn up by the Committee, the superintendence of its execution was undertaken by Mr. Scott Russell, as being the only Member of the Committee resident in or near London.

8. Full-sized drawings of the models having been prepared in conformity with the programme, the models were made from those drawings. Both drawings are now exhibited, and also model B; model A, being now in use, has not been sent to Birmingham.

9. The actual performance of the experiments was entrusted by Mr. Russell to Mr. J. Quant, Naval Architect, who has performed that duty with great skill and assiduity.

10. Twenty-eight experiments have already been made on model A, upon a run of about 98 feet in length on a lake in Blackheath Park, the use of which for that purpose has been liberally granted by Dr. Joseph Kidd. Further experiments on model A are in active progress; and when they are finished those upon model B will be begun.

11. The Committee deem it advisable to defer giving a detailed account of those experiments until the whole series shall have been completed, because the separate publication of the portion of that series which has hitherto been made would be but imperfectly useful, and also because, having only yesterday (11th Sept. 1865) received the account of those experiments, they have not had time to give them due consideration.

12. The following general results, however, may be stated:—

I. The resistance of model A when immersed so as to be just covered with water, and no more, is more than double of its resistance when half immersed at the same speed.

II. When the after-body of model A is turned so as to convert the water-lines into buttock-lines, its resistance is increased, and that whether the model is half immersed or just covered.

Report on Observations of Luminous Meteors, 1864–65. By a Committee, consisting of JAMES GLAISHER, F.R.S., of the Royal Observatory, Greenwich, Secretary to the British Meteorological Society, &c.; ROBERT P. GREG, F.G.S., &c.; E. W. BRAYLEY, F.R.S., Professor of Physical Geography and Meteorology in the London Institution, &c.; and ALEXANDER S. HERSCHEL, B.A.

THE Chairman, in presenting the Report, said, The class of phenomena known as Luminous Meteors includes the familiar appearances of shooting-stars and fireballs—in the words of M. Quetelet, “a much despised phenomenon, long neglected by astronomers,” but which now justly claims their attention, and, as shown by the papers contained in this Report, commands the consideration of those best able to speculate upon cosmical phenomena.

The number of meteors observed during the past year has been unusually small, partly owing to the cloudy state of the sky, partly owing to the absence this year of certain acknowledged star-showers, namely, those of January, April, and August. The November shower, although concealed in England by clouds, did not disappoint expectation. It attracted attention, and was observed with considerable interest at Malta, as described in the Report. If the sky is clear, the circumstances are altogether favourable for its reappearance in the present year and the next, in the morning of the 13th of November. Its greatest display is expected to visit us in 1866; but even in the present year it is advisable to be prepared for its appearance by organizing a competent staff of observers, and furnishing them with the proper means for determining the radiant-point, and the heights and velocities of the meteors. The British Association in the past year having sanctioned a set of Maps to be printed for the use of the Committee, which are now completed and are 1865,

presented with this Report, every means will be provided to Members of the Association willing to take part in the observations of this shower, to enable them to record their observations with facility, and to reduce as far as possible the inevitable uncertainty of cloudy nights, which attaches to our insular climate in November.

A shower of remarkable meteors observed on the 18th of October last (of which a map, showing the radiant-point, was exhibited), coincided with a date at which fireballs have made their appearance in more than average numbers. The radiant-point of this shower was perfectly defined in *Orion*, and illustrates well the manner in which these maps may be employed. A star-shower less conspicuous, on the 28th of July last, was observed with a radiant-point equally distinct, close to *Fomalhaut*, the most southerly star observed on our meridian. These and other accurate observations of star-showers are included in the Report. Continued observation will doubtless reveal other radiant-points, and at the same time will lead to determining more exactly the position and character of those already known.

Of large meteors, the greater number described in the Catalogue took place in December last. Two detonating meteors were also observed. The first occurred in England on the 20th of November last, the second in Scotland on the 21st of February. Observations show that on the first of these nights shooting-stars were extremely scarce, so that at Weston-super-Mare and Hawkhurst only one or two meteors could be counted in an hour. This fact, of which the description is contained in the Catalogue, illustrates in a remarkable manner the adventitious character of large meteors. Nevertheless the 20th of November is one among the well-known dates preferred by fireballs. A third detonating meteor, on the 30th of April, was doubly observed at Manchester and Weston-super-Mare, and its height was well determined. The nearest approach of this meteor to the earth was thirty-seven miles. Startling as are the accounts of detonations heard from such a height, it is yet more surprising that the report from such a distance should be brief and momentary. The sounds caused by meteors yet offer much which, it is hoped, will be explained and illustrated by further observations.

Interesting papers appear in the Report, "On the Origin of Meteorites, the series of Physical Processes of which they are the result, and their functions in Nature," by Professor Brayley; and "On the Physical History of Meteorites," by Mr. Sorby. It appears from a microscopic analysis of their structure by Mr. Sorby, that when *aërolites* resemble in their appearance igneous terrestrial rocks, the evidence of their previous history has been more or less obliterated, while characteristic peculiarities in their structure evince that they could not have originated in the volcanic action of the moon or any planet. Mr. Brayley infers that they originate in gaseous matter projected from the equator of the sun, and condensed to the solid form in its passage through interplanetary space. A gradual condensation from a vaporous state is said by Mr. Sorby also to represent more nearly than any other the conditions under which they must have been consolidated. In this view of the origin of meteorites (including in the term *Meteoric Irons*), their source is considered to be unique, and they are traced to the energetic forces whose modes of action are considered in Solar Physics. The bodies thus arising are termed by Mr. Brayley *Meteoritic Masses*, to distinguish them emphatically from all other members of the solar system, as well as from fallen meteorites.

In another paper contained in this Report, which is an abstract of a 'Memoir on Sporadic Shooting-stars,' Mr. Newton, basing his conclusions upon a certain knowledge of their height, arrives at some interesting results

regarding the number and distribution of these bodies in space. The average height of the centres of their visible tracks is sixty miles above the earth. Their number in the atmosphere daily is seven and a half millions, and, if not intercepted in their flight, there would be found in the *space* occupied by the earth at any instant in its orbit, 13,000 of such bodies pursuing different orbits. Of shooting-stars visible in telescopes, Mr. Newton calculates that the number is at least fifty times as great as the number of those visible to the naked eye. Indeed there appears to be no limit to their minuteness or to their numbers. Their velocity is greater than the velocity of the earth in its orbit, and Mr. Newton supposes that they are grouped together according to some law, probably that of rings encompassing the sun, resembling in their inclinations and dimensions the orbits of the comets. Mr. Newton, in conclusion, supposes that these bodies, which he terms *Meteoroids*, are not fragments of a former world, but rather materials from which new worlds are forming; the latter view is taken by Mr. Brayley.

Meteoroids and meteoritic masses constitute the two classes of bodies which have to be considered in Meteoric Astronomy. It is, however, reasonable to suppose that the same forces which in the phase of greatest concentration of the solar system give rise to "meteoritic masses," might in a phase of vastly greater antiquity, and of greater extension of the solar orb, have given rise in a similar manner to the rings of "meteoroids." Continued observations directed to the phenomena of shooting-stars will end by removing doubt from this province of astronomy, and throw new light on certain difficult questions in cosmical philosophy—such, for example, as the existence of organic matter (a kind of peat or humus) in the meteorites of Orgueil.

At the request of the Committee, the following Report for the past year has been drawn up by Alexander S. Herschel:—

The Committee have the satisfaction to present in this Report several descriptions of large meteors; of which the details are given in the Catalogue, and have led in some instances to determining their real heights and velocities. In investigating the path of the detonating meteor of the 30th of April last (Monthly Notices, R.A.S., 1865, June 9), although resting on two observations only, a high degree of accuracy was attainable. The Committee take this opportunity of congratulating Members and other observers on the increasing precision of their observations, by which this satisfactory result could be obtained (Appendix I. 6).

A few observations of old date, not previously recorded, are entered in the Catalogue, together with extracts from authentic foreign sources. Observations of several star-showers are included, of which the results are collected in Appendix II. Recent additions of meteorites to museums, and remarkable meteors, are described in the third and fourth appendices of the Catalogue. A number of contributions to literature in meteoric astronomy are either noticed or given in full in Appendix V.

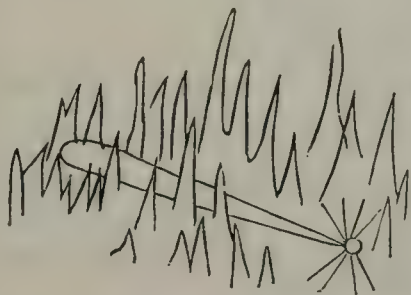
Sky-maps prepared especially for observations of shooting-stars, and particularly of their radiant-points, have been placed for constant use in the hands of observers. Dr. Heis, of Münster, warmly seconding the appeal of the Committee, has lithographed copies of these charts, by which the meteors observed in the same latitude* at Münster are conveniently compared with those observed at Greenwich. To his courteous zeal and devoted labours, the Committee are indebted for the heights of shooting-stars observed at Münster in July and August 1864 and 1865, contained in Appendix VI.

* The latitude of Greenwich Observatory is $51^{\circ} 28' 38''$: that of Münster Observatory is $51^{\circ} 53' 10''$. The difference is therefore $29' 32''$, or not quite half a degree—about the average error unavoidably committed in copying, and producing a requisite quantity of lithographic impressions of the maps.

A CATALOGUE OF OBSERVATIONS

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1781. Feb. 23	h m 11 59 (sid. time.)	Slough (Bucks).	Diameter 15'' or 16'.			
1840. July 28	Night	H.M.S. 'Erebus.' S. lat. 47°, E. long. 97°.				
1841. Aug. 9	8 29 p.m. (local time.)	H.M.S. 'Erebus.' E. long. 164° 18', S. lat. 33° 40'.	Brilliant meteor			
Dec. 10		Hawkhurst (Kent).	= 2nd mag.*			Near ζ Hydræ....
1842. Oct. 5	9 12 p.m.	Ibid	= Jupiter.			From η Pegasus across β Aquarii
1858. May 31	11 12 p.m.	Ibid	$\frac{1}{3}$ diameter of full moon.		$\frac{1}{2}$ second	At the same altitude as β, and the same azimuth as α Lyræ.
Aug. 9 to 10	11 0 p.m. 1 0 a.m.	H. M. S. 'Fury.' Off Jedo (Japan).	Magnificent meteor	Blue and orange.		In the N.N.E.
1860. Oct. 13		Baffin's Bay	Large			From near Cassiopeia, across Ursæ Minor, and losing itself in the fold of Draco.
1861. Aug. 6	About 10 p.m.	Kidderminster (Warwickshire).	Large		About 4 secs.	At an altitude of about 50°.

OF LUMINOUS METEORS.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
A telescopic meteor with a lunula.				W. Herschel (Journal of Observations).
.....			" Meteors in great numbers were seen darting about in all directions."	J. C. Ross, 'Voyage to the Southern Seas.'
.....			In one hour fifteen falling stars.	Id.
.....		Fell in a curve with one or two bends. 	Flexure not great, but certainly not straight.	J. F. W. Herschel, MS.
Left a long broad sparkling train for 5 seconds.				Id.
Left a patch of light of its own size at the place for 2 seconds.		Stationary		Id.
Burst. Left a train which lasted a minute.		Fell in the N.N.E.	Hundreds of meteors overhead shooting from N.E. to W.	Sherard Osborne (Japanese Waters).
Followed by a tail of light 20° in length.			Crossing the beams of an aurora.	C. F. Hall.
.....				
Illuminated the whole district with its light.		S. to N.; horizontal ...	Fine starlight night, no wind.	H. W. Johnston.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Mar. 21	h m s	Brisbane Observatory (Australia).				
June 23		Ibid	Brilliant meteor ...			In the W.
1863. Oct. 30	8 to 9 p.m.	Hawkhurst (Kent).	Small			
31	8 to 9 p.m.	Ibid	Small			
Nov. 1	1 30 to 2 a.m.	Ibid				
2	11 to 12 p.m.	Ibid				
1864. Aug. 3	7 50 p.m.	Cherbourg (France).	Very large, producing a strong light.	Yellow	Very slow motion.	A few degrees above the S.E. horizon.
8	10 7 p.m.	London	=2nd mag.*	Ruddy white...	$\frac{1}{2}$ second	From $\frac{1}{2}$ (η , ζ) Herculis to ϵ Coronæ.
10	9 5 p.m.	Eastbourne (Sussex).	Much brighter than Jupiter.		About 3 secs...	Passed through the Lynx.
16	About 0 40 a.m.	Altanca (St. Gotthard).	Large fireball		2 or 3 seconds	
29	9 24 p.m.	Weston - super - Mare.	=1st mag.*	Orange	3 seconds.....	From β Persei to σ Piscium.
Sept. 2	8 16 30 p.m.	Greenwich	=1st mag.*	Bluish white...	1 second	From direction of ϵ Cygni to ϵ Pegasi.
5	10 21 p.m.	Ibid	Greater than 1st mag.*	Bluish white...		Disappeared near λ Bootis; point of appearance not seen.
6	8 55 p.m.	West Linton (Scotland).	Large	Bluish		Between E. and S.E.
6	9 5 p.m.	Ibid	Large			In the N.
11	8 26 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0.6 second ...	Centre of the path at σ Cephei.
12	0 41 a.m.	Wolverhampton	=2nd mag.*	Blue	$1\frac{1}{2}$ second ...	From α Persei to θ Ursæ Majoris.
14	11 51 p.m.	Weston - super - Mare.	=Sirius	Bright white...	$\frac{1}{2}$ second	Began at 25 Lyncis
19	11 40 p.m.	Hawkhurst (Kent).	=3rd mag.*	Yellow	0.8 second ...	Midway between ρ Cygni and f Lacertæ.
20	8 21 p.m.	Ibid	=1st mag.*	Orange.....	0.8 second ; rapid.	From ξ Herculis to $\frac{1}{2}$ (α Ophiuchi, S Tauri Poniatowski).

Appearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
			Shooting-stars frequent through the night.	Pugh's Directory (1864).
			Frequent shooting-stars on the 22nd and 27th.	Id.
			In one hour, one meteor only ; clear sky.	A. S. Herschel.
			In one hour six meteors ; clear sky.	Id.
			In thirty minutes no meteor seen ; clear sky.	Id.
			In one hour no meteor seen ; clear sky.	Id.
Conical figure. Increased in size until it burst with a shower of sparks like a rocket.		W.S.W. to E.N.E.	The meteor (? the train) remained visible one minute.	'The Times.'
Left a train the same length as the path.				T. Crumplen.
	5° or a little more.		In twilight	G. F. Chambers.
Left a white streak for several minutes : broad and long, and chan- ging its form and colour to yellow and red.		E. to W.	Sky cloudless ; the light of the meteor re- sembled noonday ; dazzling.	Modena News- paper.
Reddish train, 15° in length			Slow motion	W. H. Wood.
Train		Perpendicular		W. C. Nash.
	5° + ...	Nearly perpendicular ...	Slow motion	Id.
Burst like a shell, illu- minating the heavens with a brilliant light.				Walter Bell.
Left a long train of light, which remained visible after the meteor itself had disappeared.			On the same night a number of other me- teors were seen, mostly large.	Id.
	5°	Directed from η Cephei..		A. S. Herschel.
				T. M. Simkiss.
	10°	Downwards towards the right 20° from per- pendicular.	Moonlight	W. H. Wood.
	2°	Almost stationary	No other shooting-star in 50 minutes.	A. S. Herschel.
No train or sparks				Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Sept. 20	h m 10 35 p.m.	Hawkhurst (Kent).	=Capella, then= 2nd or 3rd mag.*	White, then red.	3 seconds; very slow.	From σ Persei to $\frac{1}{2}$ (α , η) Aurigæ.
	20 10 58 p.m.	Ibid	=2nd mag.*	Orange	0.8 second; rapid.	To $\frac{2}{3}$ (α Andromedæ, γ Pegasi), $\frac{3}{4}$ of the way from α Triangulæ.
	22 11 52 p.m.	Ibid	=2nd mag.*	White	0.6 second ...	From ϵ to λ Piscium
	22 11 59 p.m.	Ibid	=3rd mag.*	White	0.7 second ...	Began at β Arietis
	23 8 36 p.m.	Ibid	= α Lyræ	White	1.2 second ...	Centre of path at α Cygni; disap- peared between ν and ξ Cygni.
	23 8 48 p.m.	Ibid	=3rd mag.*	White	1.2 second ...	From Q Camelo- pardi to α Ursæ Majoris.
	23 8 49 p.m.	Ibid	=3rd mag.*	White	1 second	From γ Lacertæ to ϵ Cephei.
	23 8 50 p.m.	Ibid	=3rd mag.*	White	1 second	From γ Ursæ Mi- noris to $\frac{1}{2}$ (g , η) Draconis.
	23 8 54 p.m.	Ibid	=3rd mag.*	White	1 second ...	Disappeared mid- way between ξ and ϵ Pegasi.
	23 8 55 p.m.	Ibid	=3rd mag.*	White	1 second	Midway between ϵ and g Pegasi.
	23 8 59 p.m.	Ibid	=3rd mag.*	White	1.4 second ...	From r Vulpeculæ to 4° beyond β Cygni.
	23 9 54 p.m.	Ibid	=3rd mag.*	Yellow	0.5 second; rapid.	From α Androme- dæ to $\frac{2}{3}$ (γ , α) Pegasi.
	24 0 20 a.m.	Mont de Marsan (S. France).	Fireball; large, like a bombshell.		Moved rapidly	
	24 8 26 p.m.	Hawkhurst (Kent).	=1st mag.*	White	0.6 second ...	From 2° W. of q Ca- melopardi, half- way to c Lyncis.
	24 8 37 p.m.	Ibid	=3rd mag.*	White	1.2 second ...	From $\frac{1}{2}$ (δ Coronæ, π Serpentis) to 4° beyond κ Ser- pentis.
	24 8 53 p.m.	Ibid	=3rd mag.*	Yellow	0.5 second ...	Began at κ Ophi- uchi.
	24 9 29 p.m.	Ibid	=3rd mag.*	White	0.4 second ...	From $\frac{1}{2}$ (a , b) to c Draconis.
	24 9 32 p.m.	Ibid	=3rd mag.*	Yellow	0.6 second ...	Disappeared at $\frac{1}{3}$ (K Cerberi, β Cygni).
	24 9 38 p.m.	Ibid	= α Lyræ, then= 2nd or 3rd mag.*	White, then red.	3.4 seconds ...	From $\frac{1}{2}$ (ζ , b) Ursæ Minoris to K Ca- melopardi.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Diminished in midway to a dull red star, drawing a tail of red sparks.	15°	Radiant, θ Ceti		A. S. Herschel.
No train or sparks	20°			Id.
No train or sparks				Id.
No train or sparks	8°	Directed from α Triangulæ.		Id.
No train or sparks				Id.
No train or sparks				Id.
No train or sparks				Id.
No train or sparks				Id.
No train or sparks				Id.
No train or sparks	8°	Direction from $\frac{1}{2}$ (ι , κ) Pegasi.		Id.
No train or sparks		Stationary		Id.
Intermittent light				Id.
No train or sparks	15°	Radiant, β Aurigæ		Id.
A ball of fire		N. to S.	A report equal to twenty pieces of cannon fired off to- gether, followed the meteor, lasting 10 seconds. During sunshine. (See Ap- pendix III.)	'La Gironde' Newspaper.
No train or sparks				A. S. Herschel.
No train or sparks				Id.
No train or sparks	6°	Directed from ϵ Herculis. Radiant, β Aurigæ.		Id.
No train or sparks				Id.
No train or sparks	12°	Directed from δ Cygni.		Id.
aming nucleus, drawing a tail of red sparks.			A singular shooting-star	Id.

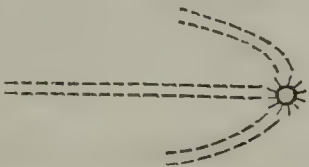
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Sept. 24	h m 9 42 p.m.	Hawkhurst (Kent).	=3rd mag.*	Yellow	0.7 second ...	Disappeared at $\frac{1}{2}$ (γ , δ) Bootis.
24	9 47 p.m.	Ibid	=3rd mag.*	White	0.7 second ...	From α to β Cephei
24	11 3 p.m.	Ibid	=3rd mag.*	Yellow	0.3 second ...	From O Camelpardi to γ Ursæ Minoris.
24	11 13 p.m.	Ibid	=3rd mag.*	White	0.8 second ...	To $\frac{1}{2}$ (ζ , θ) Cassiopeiae, halfway from μ Andromedæ.
24	11 15 p.m.	Wolverhampton	=1st mag.*	White	1½ second ...	From κ Draconis to ζ Herculis.
24	11 32 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1 second	From $\frac{1}{3}$ (δ , α) Aurigæ to $\frac{1}{3}$ (δ) Camelpardi, δ Persei).
24	11 44 p.m.	Ibid	=3rd mag.*	White	1.2 second ...	From $\circ$ to η Cygni.
24	11 47 p.m.	Ibid	=2nd mag.*	White	0.7 second ...	From α Piscium to θ Ceti.
25	8 43 p.m.	Ibid	=2nd mag.*	Yellow	0.8 second ...	From $\frac{1}{3}$ (γ , ξ) to μ Draconis.
25	8 45 p.m.	Ibid	=3rd mag.*	Yellow	1 second	From $\frac{1}{4}$ (α , δ) to γ Ursæ Majoris.
25	9 44 p.m.	Wolverhampton	=2nd mag.*	Orange.....	1½ second ...	From α Lyræ to α Draconis.
25	11 45 p.m.	Ibid	=2nd mag.*	Blue	2 seconds.....	From α Aquarii to α Herculis.
26	0 30 a.m.	Ibid	=2nd mag.*	Blue	1½ second ...	From α Ceti to α Aquarii.
26	8 2 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0.6 second ...	From A Custodis to II Camelpardi.
26	8 4 p.m.	Ibid	=3rd mag.*	White	1 second	From n Tarandi to $\frac{1}{2}$ (K, BAC 2326) Camelpardi.
26	9 50 p.m.	Weston - super - Mare.	Large fireball	White		Fell to the W.N.W. horizon from an altitude of about 30°.
26	11 30 p.m.	Wolverhampton	2×Mars	Golden yellow	2 seconds.....	Began near Polaris.
27	7 48 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0.9 second ...	Began at χ Cygni...

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
.....	4°	Directed from ν Bootis..		A. S. Herschel.
.....			In two hours nineteen meteors.	Id.
.....	15°		Radiant, β Aurigæ	Id.
.....			In one hour eleven me- teors.	Id.
.....				Communicated by T. M. Sim- kiss.
Left a bright streak for 2 seconds.	10°		Radiant, β Aurigæ	A. S. Herschel.
Left a train	15°		Radiant, β Aurigæ	Id.
Left a train	15°		Radiant, β Aurigæ	Id.
.....				Id.
At first a ruddy 3rd magnitude star. At the moment of dis- appearance it flashed with a light nearly equal to Jupiter, leav- ing a luminous spot at the place for four seconds.	6°		In one hour eight shoot- ing-stars.	Id.
Left a short train				T. M. Simkiss.
.....			Meteors very frequent through the night.	Id.
.....				Id.
.....				A. S. Herschel.
.....			In one hour eleven me- teors.	Id.
.....		Downwards towards the left, 15° or 20° from perpend'cular.		Communicated by W. H. Wood.
Left a short train separated from the head, thus—		E. to W., nearly hori- zontal.		Communicated by T. M. Sim- kiss.
	7°	Directed from $\frac{1}{2}$ (α , δ) Cygni.		A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Sept. 27	h m 7 52 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0.7 second ...	From γ Draconis to ι Herculis.
27	8 7 p.m.	Ibid	= α Lyræ, then = 2nd or 3rd mag.*	White, then red.	4 seconds.....	From δ Aquilæ to $\frac{2}{3}$ (β , α) Ophiuchi.
27	8 16 p.m.	Ibid	=2nd mag.*	Yellow	1.6 second ...	From ι Persei to $\frac{1}{2}$ (α , B) Camelopardi.
27	8 34 p.m.	Ibid	=3rd mag.*	White	1.5 second ...	From g Lacertæ to μ Cephei.
27	8 44 p.m.	Ibid	=3rd mag.*	Yellow	0.8 second ...	From γ Cygni to α Sagittæ.
27	8 44 p.m.	Ibid	=3rd mag.*	White	0.5 second ...	From e Custodis to $\frac{1}{4}$ (ι , ϵ) Cassiopeiæ.
27	8 52 p.m.	Ibid	= α Lyræ	Fine yellow ...	3.8 seconds ...	From π Cassiopeiæ to π Cephei.
27	9 1 p.m.	Ibid	=3rd mag.*	Yellow	0.6 second ...	From $\frac{1}{2}$ (ρ , δ) Draconis to $\frac{1}{2}$ (γ Draconis, κ Cygni).
27	9 14 p.m.	Ibid	= Sirius	Red, then white.	0.8 second ...	Began at α Aquarii
27	9 37 p.m.	Ibid	=3rd mag.*	Yellow	1.3 second ...	From $\frac{1}{2}$ (λ Andromedæ, g Lacertæ to e Pegasi).
27	9 50 p.m.	Ibid	=2nd mag.*	Yellow	0.5 second ...	From $\frac{1}{2}$ (ζ , μ) Cygni halfway to α Delphini.
27	9 53 p.m.	Ibid	=2nd mag.*	White	0.6 second ...	Began at ζ Cephei..
27	9 55 p.m.	Ibid	=3rd mag.*	White	1.4 second ...	From β Cephei to $\frac{2}{3}$ (ψ Draconis, γ Ursæ Minoris).
27	10 27 p.m.	Ibid	=3rd mag.*	Yellow	0.6 second ...	From $\frac{1}{3}$ (S, L) Camelopardi to $\frac{1}{4}$ (Polaris, P Camelopardi).
27	11 11 p.m.	Ibid	=3rd mag.*	White	1.1 second ...	To d Telescopii, $\frac{3}{4}$ of the way from θ Aurigæ.
27	11 14 p.m.	Ibid	=3rd mag.*	Yellow		From $\frac{1}{2}$ (ϕ , χ) Persei to $\frac{2}{3}$ (θ , κ) Andromedæ.
29	2 5 a.m.	Wolverhampton	> Mars	Golden yellow	2½ seconds ...	In the E., altitude 35°.
30	9 15 p.m.	Ibid	=1st mag.*	Yellow, then green.		About 20° above the E.N.E. horizon.
Oct. 5	10 46 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1.1 second ...	From $\frac{1}{2}$ (h Ursæ Majoris, λ Draconis) to δ Ursæ Majoris.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
.....				A. S. Herschel.
Diminished in midway to a dull red star, drawing a tail of red sparks.	30°	Radiant, θ Ceti		Id.
.....	15°	Radiant, θ Ceti		Id.
Began suddenly, gradually grew less.				Id.
.....	12°	Radiant, β Aurigæ		Id.
.....			In one hour twelve me- teors.	Id.
Drop-like nucleus, with a tail of yellow sparks.	30°	Path undulating. Ra- diant, θ Ceti.	In one hour twelve me- teors.	Id.
.....	15°	Radiant, β Aurigæ		Id.
.....		Towards δ Aquarii		Id.
Left a train	35°	Radiant, β Aurigæ		Id.
.....	10°	Radiant, β Aurigæ		Id.
.....	4°	Directed from α Cephei	In one hour ten meteors	Id.
.....	20°	Radiant, θ Ceti		Id.
.....	15°	Radiant, β Aurigæ		Id.
.....	15°	Radiant, θ Ceti		Id.
.....		Radiant, β Aurigæ	In one hour eleven me- teors.	Id.
o train left		Horizontal. S. to N. ...		Communicated by T. M. Sim- kiss.
.....				Id.
Left a train for 1 second on the whole length of its path.		 		A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Oct. 5	h m 10 49 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1.5 second ...	From β Aurigæ to ϵ Lyncis and 6° further.
	5 10 56 p.m.	Ibid	=3rd mag.*	Dull	0.9 second ...	From α Andromedæ to $\frac{1}{2}$ (β, μ) Pegasi.
	5 11 40 p.m.	Kensington (London).	=2nd mag.*		Not more than 3 seconds.	From R. A. $16^h 50^m$, N. Decl. $67\frac{1}{2}^\circ$, to R. A. $11^h 20^m$, N. Decl. 60° .
	6 8 9 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1 second	To λ Andromedæ, $\frac{2}{3}$ of the way from ϵ Lacertæ.
	6 8 15 p.m.	Ibid	=2nd mag.*	White	1 second	From η Piscium, halfway to β Arietis.
	6 11 10 p.m.	Wolverhampton	$2 \times$ Mars	Blue and red..	3 seconds.....	From η to ζ Tauri..
	8 0 20 a.m.	Ibid	=Mars		2 seconds.....	About 30° above W.S.W. horizon.
	8 0 50 a.m.	Ibid	=Sirius	Blue	2 seconds.....	About 20° above the E.S.E. horizon.
	10 2 32 a.m.	Ibid	=1st mag.*.....	Green	$1\frac{1}{2}$ second ...	From γ Cassiopeiæ to α Cygni.
	10 2 40 a.m.	Ibid	$3 \times$ Sirius.....	White	Fully $3\frac{1}{2}$ secs.; very slow motion.	About 35° above the E. horizon.
	11 3 0 a.m.	Ibid	=1st mag.*	White	1 second; very rapid.	From $\frac{1}{2}$ (α, β) Geminorum to Rigel.
	13 0 45 a.m.	Hawkhurst (Kent).	=3rd mag.*	White	0.5 second ...	From ϵ to $\frac{1}{2}$ (κ, α) Persei.
	13 0 56 a.m.	Ibid	=3rd mag.*	White	0.6 second ...	Began at $\frac{1}{2}$ (L Camelopardi, δ Lyncis).
	13 2 30 a.m.	Wolverhampton	$2 \times$ Mars	Golden yellow		About 30° above the S.E. horizon.
	18 9 52 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	1.2 second ...	Began at f Lacertæ
	18 10 13 p.m.	Ibid	=3rd mag.*	White, then red.	1.3 second ...	Began at $\frac{1}{2}$ (ϵ Ursæ Minoris, χ Draconis).

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a train for 1 second in the first half of its course.				A. S. Herschel.
Left a faint train visible half a second.				Id.
				G. F. Chambers.
				A. S. Herschel.
				Id.
Left a long bright train ...				Communicated by T. M. Sim- kiss.
Left a long bright train ...			Meteors very frequent through the night.	Id.
Left a long bright train ...				Id.
				Id.
Left a short train				Id.
Small fireball, throwing off sparks, and leaving a long train.		N. to S. Horizontal ...		Id.
				Id.
				A. S. Herschel.
	6°	Directed from $\frac{1}{3}$ (c, d) Camelopardi.		Id.
				Communicated by T. M. Sim- kiss.
	6°	Directed towards β Pe- gasi.		A. S. Herschel.
Left in the last half of its course.	15°	Directed from η Cephei		Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Oct. 18	h m 10 20 p.m.	Hawkhurst (Kent).	= α Lyræ	Blue, with short red tail.	2.7 seconds ...	From $\frac{1}{2}$ (L, M) Camelopardi to $\frac{1}{2}$ (ζ , ω) Draconis.
	18 10 22 p.m.	Ibid	= α Lyræ	Blue, with short red tail.	2.5 seconds ...	From $\frac{1}{2}$ (P, N) Camelopardi across β Ursæ Minoris to $\frac{1}{3}$ (η , ξ) Draconis.
	18 10 26 p.m.	Ibid	= 1st mag.*	White	1.3 second ...	From near σ Piscium to $\frac{1}{2}$ (α Andromedæ, β Pegasi).
	18 10 43 p.m.	Ibid	= 3rd mag.*		0.6 second ...	Began at $\frac{1}{2}$ (α Arietis, β Triangulæ).
	18 10 52 p.m.	Ibid	> 1st mag.*	Bright white..	1 second	Midway between ϵ and θ Geminorum.
	18 10 58 p.m.	Ibid	= 3rd mag.*	White	1.4 second ...	From κ Cephei to $\frac{1}{2}$ (ζ , ω) Draconis.
	18 11 2 p.m.	Ibid	= 2nd mag.*		1 second	From γ Cassiopeiæ three quarters of the way to α Cygni.
	18 11 12 p.m.	Ibid	= 3rd mag.*		0.5 second ...	Began at $\frac{1}{3}$ (ζ Persei, η Tauri).
	18 11 14 p.m.	Ibid	= α Lyræ	Orange	1.6 second ...	From ζ Cassiopeiæ to τ Cygni.
	18 11 27 p.m.	Ibid	= 2nd mag.*		1.2 second ...	Centre of path at L Camelopardi.
	18 11 50 p.m.	Ibid	= 2nd mag.*		0.8 second ...	From $\frac{1}{4}$ (P Camelopardi, Polaris) to $\frac{1}{3}$ (ϵ , ζ) Ursæ Minoris.
	18 11 52 p.m.	Ibid	= 2nd mag.*		0.8 second ...	From 1° N. of δ Persei to $\frac{1}{2}$ (B, C) Camelopardi, and 4° further.
	18 11 58 p.m.	Ibid	= Mars	Blue, with short red tail.	1.5 second ...	From $\frac{2}{3}$ (ζ Persei, δ Muscæ) to $\frac{1}{2}$ (ν , ι) Andromedæ.
	19 0 2 a.m.	Ibid	= 2nd mag.*		0.6 second ...	From $2\frac{1}{2}^{\circ}$ S. of ϵ Muscæ to α Arietis.
	19 0 7 a.m.	Ibid	= 3rd mag.*		0.6 second ...	From μ to ξ Ceti and 30° further.
	19 0 14 a.m.	Ibid	= 2nd mag.*		0.4 second ...	Began 2° S. of Cassiopeiæ.
	19 About 8 p.m.	Malton.....	Large as a rocket...	Bluish white...	Slow speed ...	Disappeared near the S.S.W. horizon.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a train on the whole length of its path for $2\frac{1}{2}$ seconds.	40°	Radiant, ν Orionis		A. S. Herschel.
Left a red train on the whole length of its path for $2\frac{1}{2}$ seconds.	30°	Radiant, ν Orionis	The course appeared bent at β Ursæ Minoris.	Id.
Left a train for $1\frac{1}{2}$ second on the whole length of its path.	25°	Radiant, ν Orionis		Id.
.....	10°	Directed from the Pleiades. Radiant, ν Orionis.		Id.
stationary meteor. Left a patch of light like a star, which remained visible 5 secs.				Id.
.....				Id.
.....	25°	Radiant, ν Orionis		Id.
.....	6°	Directed from α Tauri. Radiant, ν Orionis.		Id.
Left a bright yellow train on the whole length of its course for $3\frac{1}{2}$ seconds.	38°	Radiant, ν Orionis		Id.
Left a train for 1 second...	12°	Directed from β Aurigæ. Radiant, ν Orionis.		Id.
Left a train on the whole length of its course visible 2 seconds.	14°	Radiant, ν Orionis		Id.
Left a train for 2 seconds	13°	Radiant, ν Orionis		Id.
Left a wide yellow train on the whole length of its course visible four seconds; widest in the middle of the course.	32°	Radiant, ν Orionis		Id.
.....	8°	Radiant, ν Orionis		Id.
.....	12°	Radiant, ν Orionis		Id.
Left a white train on the whole length of its path visible 2 seconds.	8°	Directed from $\frac{1}{2}$ (ϕ , ν) Persei. Radiant, ν Orionis.		Id.
Left intensely bright. Left a long streak for some seconds.		N.N.E. to S.S.W.	A dark night, illuminated all objects sufficiently to recognize them.	The Times.'

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Oct. 19	h m: 11 28 p.m.	Hawkhurst (Kent).	=1st mag.*	Yellowish white.	1.3 second ...	From 3° S. of Tauri, $\frac{3}{4}$ of the way to $\frac{1}{2}$ (β , α Arietis.
	19 11 43 p.m.	Ibid	=2nd mag.*	Bright white...	1.2 second ...	Began at β Arietis.
	20 8 8 p.m.	Ibid	=3rd mag.*	White	1.2 second ...	Disappeared at Piscium.
	20 8 10 p.m.	Ibid	=3rd mag.*	White	1 second	From γ to $\frac{1}{2}$ (α , β Equulei.
	20 8 30 p.m.	Ibid	=3rd mag.*	White	0.6 second ...	At L Camelopardi
	20 9 16 p.m.	Ibid	=2nd mag.*	Bright white...	0.4 second ...	At $\frac{1}{2}$ (ϵ , δ) Draconis.
	20 9 34 p.m.	Ibid	=3rd mag.*	Yellow	0.9 second ...	From $\frac{1}{2}$ (A Custodis, H Camelopardi) to 3° beyond C Camelopardi.
	20 9 37 p.m.	Ibid	=2nd mag.*	White	1 second	To B, halfway from F Cerberi.
	20 9 39 p.m.	Ibid	=3rd mag.*	Yellow	0.9 second ...	From $\frac{1}{2}$ (A Custodis, H Camelopardi) to ϵ Camelopardi.
	22 10 48 p.m.	Greenwich	=1st mag.*; brilliant.	Blue		Across Aldebaran.
	24 7 12 p.m.	Ibid	=2nd mag.*; bright.	Blue	Rapid motion..	Directed toward horizon; path parallel to a line joining α Andromedæ and α Pegasi, at a distance of 20° from Pegasi.
	24 9 16 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	1.2 second ...	Began at $\frac{1}{2}$ Delphini, ϵ Pegasi).
	24 9 26 p.m.	Ibid	=3rd mag.*	Bright white...	1.8 second ...	From θ Piscium to 5° beyond $\frac{1}{2}$ (Π_2 Pegasi, π Aquarii).
	24 9 49 p.m.	Ibid	=3rd mag.*	White	0.7 second ...	Disappeared at Eridani.
	24 10 32 p.m.	Ibid	=3rd mag.*	White	0.8 second ...	From ϵ Pegasi to 4° beyond Equulei.
	24 10 49 p.m.	Ibid	=3rd mag.*	White	1.2 second ...	From β Eridani β Orionis.
	25 11 19 p.m.	Ibid	=2nd mag.*	White	1.4 second ...	From $\frac{1}{2}$ (ϵ Muscæ p Persei) to (γ Pegasi, α Andromedæ).

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a streak the whole way for 2 seconds.		From Radiant, ν Orionis		A. S. Herschel.
	5°	Directed towards κ An- dromedæ.	No other shooting-star in 45 minutes.	Id.
	5°	Directed from β Arietis		Id.
			Another followed the same path on the 23rd.	Id.
Left a patch of light for 2 seconds.	1°	Nearly stationary		Id.
A stationary meteor		Stationary		Id.
				Id.
				Id.
				Id.
		N. to S., horizontal	Cloudy sky. The posi- tion could not be de- finitely determined.	W. C. Nash.
	12°	α Andromedæ. * * β Pegasus. * γ * α 		Id.
	12°	Directed from $\frac{1}{2}$ (α Cygni to α Lyræ).		A. S. Herschel.
				Id.
	5°	Directed from Aldebaran		Id.
Left a streak for 2 seconds				Id.
Left a streak for 2 seconds				Id.
Left a streak on all its course for 2½ seconds.				Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Oct. 30	h m 7 7 p.m.	Tunbridge(Kent)	=Mars	Same colour as Mars.		Began a few degrees E. of the zenith.
31	11 0 p.m.	Hawkhurst (Kent)	=3rd mag.*	White	1·2 second ...	Began at m Monocerotis.
Nov. 1	2 5 a.m.	Ibid	=3rd mag.*	White	0·8 second ...	From ω_2 to α Tauri.
1	2 14 a.m.	Ibid	=3rd mag.*	White	0·7 second ...	To ψ Cancri, halfway from n Lyncis.
1	2 17 a.m.	Ibid	=3rd mag.*	White	0·8 second ...	To B, halfway from τ Tauri.
1	2 32 a.m.	Ibid	=3rd mag.*	White	0·4 second ...	From η to ν Geminorum.
4	0 15 a.m.	Ibid	=3rd mag.*	White	0·8 second ...	From T to τ Cephei.
4	0 17 a.m.	Ibid	=3rd mag.*	Yellow	0·9 second ...	From e Leonis Minoris to $\frac{2}{5}$ (54 Leonis Minoris ζ Leonis).
4	0 40 a.m.	Ibid	=3rd mag.*	Yellow	0·6 second ...	From σ to ν Piscium, and half as far again.
4	0 47 a.m.	Ibid	=3rd mag.*	White	0·9 second ...	From β Ursæ Minoris to N Draconis.
4	0 58 a.m.	Ibid	=3rd mag.*	White	0·8 second ...	From f to ν Leonis Minoris and half as far again.
4	1 0 a.m.	Ibid	=3rd mag.*	White	0·6 second ...	From σ Lyncis to ξ Ursæ Majoris.
4	3 0 a.m.	Ibid	=3rd mag.*	Yellow	1·2 second ...	From D Ursæ Majoris to α Ursæ Majoris, λ Draconis).
4	3 6 a.m.	Ibid	=3rd mag.*	White	0·5 second ...	From ξ to τ Ursæ Minoris.
4	8 10 p.m.	Ibid	=4th mag.* and =5th mag.*	Yellow	0·5 second ...	From S Vulpeculæ to ρ Aquilæ.
4	8 28 p.m.	Ibid	=3rd mag.*	White	0·6 second ...	From g to i Vulpeculæ.
4	9 16 p.m.	Ibid	=3rd mag.*	White	1·3 second ...	From $\frac{1}{2}$ (η , ρ) Piscium to $\frac{1}{3}$ (5 Piscium, γ Pegasi).
4	9 40 p.m.	Ibid	=3rd mag.*	White	1 second	From 26 to μ Draconis.
7	2 46 a.m.	Ibid	=3rd mag.*	White	0·7 second ...	From ζ to ω_2 Tauri.
7	2 49 a.m.	Ibid	=2nd mag.*	White	0·8 second ...	From g Lyncis to Geminorum.
7	2 53 a.m.	Ibid	=2nd mag.*	White	1·3 second ...	From $\frac{1}{2}$ (α , β) Geminorum to Cancri.
7	3 13 a.m.	Ibid	=1st mag.*	Yellow, then red.	1 second	3° below α Hydræ.

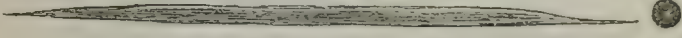
Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a train on the whole length of its path.	15°	Downwards towards S.S.E. horizon.		T. Crumplen.
.....	8°	Directed from Orion ...	From Radiant, ξ Persei.	A. S. Herschel.
.....			From Radiant, ξ Persei.	Id.
.....			From Radiant, λ Lyncis.	Id.
.....			From Radiant, ξ Persei.	Id.
.....		From Radiant, ξ Persei.	In one hour six meteors; clear sky.	Id.
Left a streak for 3 seconds			From Radiant, ξ Leonis	Id.
.....			From Radiant, ξ Persei.	Id.
.....			From Radiant, ξ Persei.	Id.
.....			From Radiant, λ Lyncis	Id.
.....			From Radiant, ξ Persei.	Id.
.....		From Radiant, ξ Persei.	In one hour nine meteors; clear sky.	Id.
.....			From Radiant, ξ Persei.	Id.
.....				Id.
Two meteors simulta- neous, about one degree apart.			Coextensive and parallel flights.	Id.
No train or sparks				Id.
Disappeared suddenly				Id.
.....			In one hour five meteors; clear sky.	Id.
No train or sparks				Id.
No train or sparks				Id.
.....				Id.
No train or sparks		Stationary	Appeared to oscillate	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Nov. 7	h m 3 36 a.m.	Hawkhurst (Kent).	= 3rd mag.*	White	0.4 second ...	From ϵ Leonis to α Virginis.
7	3 45 a.m.	Ibid	= 3rd mag.*	White	0.5 second ...	From π Leonis, half-way to α Hydrae.
7	3 50 a.m.	Ibid	= 1st mag.*	White	0.5 second ...	From ϵ Lyncis to $\frac{1}{2}$ (57 Telescopii, β Aurigæ).
8	2 20 a.m.	Ibid	= 3rd mag.*	White	0.4 second ...	From α Leonis Minoris to γ Ursæ Majoris, and half as far again.
8	2 32 a.m.	Ibid	= 3rd mag.*	White	0.5 second ...	From δ Ursæ Minoris to $\frac{1}{2}$ (β , κ) Cephei.
8	2 51 a.m.	Ibid	= 3rd mag.*	White	0.4 second ...	From M to Q Camelopardi.
9	10 23 p.m.	Greenwich	= 1st mag.*; brilliant.	Bluish white..		Fell in N.N.W. from altitude 20° to about altitude 10° ; point of appearance perpendicularly below γ Draconis.
11	5 26 p.m.	Rhodesz (S. France), Dep. Aveyron.		White, red, and blue.	3 or 4 seconds	Passed 25° W. of the zenith.
11	5 35 p.m.	West Peckham, Maidstone (Kent).	= to Venus	Colourless ...	Deliberate speed.	Disappeared 12° above the S. by E. horizon.
11	5 35 p.m.	Pamiers (S. France), Dep. Ariège.	Very brilliant meteor.		Moderate speed.	20° above the N. horizon.
11	About sun-set.	Chambon (France), Dep. Creuse.	Larger than full moon.		3 seconds.....	Passed over the valley from W.N.W. to S.S.W.
11	5 35 p.m.	Hawkhurst (Kent).	$2\times$ Venus.....	Green	5 or 6 seconds	From ϵ Ceti to α Piscis Australis.
13	12 0 a.m. to 4 0 a.m.	S. S. 'Ellora,' off Malta.				

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
.....				A. S. Herschel.
left a streak for 2 seconds				Id.
left a streak for $2\frac{1}{2}$ secs...			In one hour seven meteors; clear sky, frosty.	Id.
No train or sparks				Id.
No train or sparks				Id.
brushy appearance			In 45 minutes six meteors. Sky foggy. Overcast on succeeding days.	Id.
.....	10°			W. C. Nash.
rain straight, linear, dazzling white. Soon it enlarged and diminished in brilliancy. At the end of 5 minutes it remained as a somewhat irregular reddish cloud, 12° or 15° long and 1° or 2° wide, composed of cherry-red and dark-red sparks.	70° or 80° ...	Nearly from N. to S. ...	Eclipsed the moonlight. Seen also at Blaye and at Perigueux.	M. Boissy (Comptes Rendus, vol. lix. No. 20).
left a tapering train 4° or 5° long.	15°	Nearly horizontal	The tail was almost as brilliant as the meteor.	E. Jones.
n elongated globe; separated into portions and disappeared suddenly; left a long train on its whole course.		E. to W., horizontal	Cloudless sky. No de- tonation. Train of the same appearance as the meteor; re- mained visible four minutes.	Abbé Sans (Les Mondes).
like a firebrand, elongated behind with diffused light.		N. to S.		Legrip (Cosmos).
left a tapering train for 10 seconds of the same colour as the meteor.	12°	Directed from Capella...	Seen in twilight	A. S. Herschel and H. T. Humphreys.
.....			Grand display of meteors all through the watch None on the morning of the 14th. (See Appendix II. 2.)	Communicated by A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Nov. 13	h m 11 27 p.m.	Hawkhurst (Kent).	= 2nd mag.*	White	1 second	From β Aurigæ, halfway to λ Draconis.
	13 11 41 p.m.	Ibid	= 1st mag.*	White	4 seconds ..	From 55 Persei to $\frac{1}{2}$ (γ , ϕ) Pegasi.
	14 0 0 to 2 15 a.m.	Trafalgar Square (London).				
	20 8 40 p.m.	Leamington (Warwickshire).	Brilliant meteor ...	Green	A few seconds	In the N.E. sky ...
	20 8 50 p.m.	Beeston Observatory.	Larger than the moon.	Blue	2 seconds.....	
	20 8 55 p.m.	Mobberly (N. Cheshire).	Large meteor	At first red; then dazzling bluish white.		Almost from the zenith, falling downwards in the N.E. through about 45°.
	20 8 55 p.m.	Hallaton, Uppingham (Rutland).	As bright as the sun.	Bluish white..		Appeared first near the horizon in the N.E., and travelling westward, disappeared at an altitude of about 60°.
	20 8 57 p.m.	Weston - super - Mare.	Half the size of the moon; light like lightning.	Vari-coloured; head orange.	Moved slowly, about 3 secs.	From R.A. 164°, N. Decl. 67°, to R.A. 158°, N. Decl. 50°.
	20 A few minutes before 9 p.m.	Manchester	Vivid meteor	Blue	A few seconds	From near Capella to near Mars.
	20 9 0 p.m.	Luton (Oxon)...	Splendid meteor...	Blue and orange.		Fell to the N.E. by E. horizon.
	20 About 9 p.m.	Headingley	A ball of fire	Blue	Very brief ...	The flash appeared to come from the W.
	20 10 0 to 12 p.m.	Hawkhurst (Kent).	Six small meteors in two hours.			
	20 11 1 p.m.	Ibid	= 3rd mag.*	White	1 second	Disappeared at $\frac{1}{4}$ (η Tauri, ϕ Persei).
	22 6 20 p.m.	Ibid	= 2nd mag.*	Orange	1.3 second ..	From ϵ Tauri to ϵ Psalterii.
	22 9 17 p.m.	Greenwich	= 2nd mag.*	Blue	Less than 1 second.	In N.; point of appearance 10° above ζ Ursæ Majoris, pursued an almost horizontal path 12° westward.
	22 11 20 p.m.	Weston - super - Mare.	= 2nd mag.*	Blue		From R.A. 20°, S. Decl. 13°, to R.A. 9°, S. Decl. 11°.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
.....	15°			A. S. Herschel.
Left a streak on all its course for 3 seconds.	60°		A fine meteor. Afterwards quite overcast.	Id.
.....			Sky overcast. Heavy rain before morning.	T. Crumplen.
Disappeared with a very vivid flash of light.			Sky cloudy; a few stars visible.	M. G. Horsley.
Exploded into three fragments, which moved, one perpendicularly down, the other two, one on either side, at an angle of 60°.		Perpendicular, down ...	Imperfect view through fog. Light equal to that of day.	E. J. Lowe.
First diminished, and again flashed forth more bright than sheet lightning. Disappeared without any sparks.		Towards N.E.	Seen through clouds which obscured the stars. No report heard.	Proc. Brit. Met. Soc., ii. 324.
.....			Stars obscured by stratus cloud. About nine o'clock there was a rumbling noise as of distant cannon firing, which lasted several seconds.	'The Times,' Nov. 23.
First with orange sparks and streamers and vivid light. Tail blue.		Fell perpendicularly ...	No other meteors seen; in one hour one meteor only.	W. H. Wood.
Appeared with magnificent blue light.	About 20°		Nearly as bright as noonday; sky cloudy. A few stars visible.	R. S. Bibby.
Effulgent globe, followed by another equally brilliant but of smaller size.			Lit up the landscape ...	J. F. Hawkins.
.....				'Evening Star.'
.....		Radiating from η Tauri	Sky generally clear; no moon.	A. S. Herschel.
Increased gradually and disappeared suddenly.	5°	Directed from A Tauri...		Id.
.....				Id.
Shy appearance; pursued by a streak.				Id.
Train	12°+	Nearly horizontal, E. to W.		W. C. Nash.
.....				W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Nov. 28	h m 7 53 p.m.	Hawkhurst (Kent).	= 2nd mag.*	White	1 second	From κ Pegasi $\frac{1}{3}$ (α Delphini Vulpeculæ).
28	9 13 p.m.	Ibid	= 3rd mag.*	White	0.5 second ...	To ι , halfway from α Draconis.
28	9 50 p.m.	Wisbech (Cambridgeshire).	= α Orionis; very bright.	Yellow	2 seconds.....	From η Persei ι Tauri.
						
View just before disappearance. The head seemed to separate from the train sharp and clear like a drop of liquid metal, and then the train brightened up.						
28	10 30 p.m.	Weston - super - Mare.	= 3rd mag.*			From H_2 to 10 C melopardi.
29	1 30 a.m.	Hawkhurst (Kent).	= 2nd mag.*	White	0.5 second ...	From $\frac{1}{3}$ (η , β) H dræ to σ Mon cerotis.
29	1 36 a.m.	Ibid	= 3rd mag.*	White	0.6 second ...	From ω to ν Urs Majoris.
29	1 37 a.m.	Ibid	= 2nd mag.*	White	0.5 second ...	From d Ursæ Majoris to λ Dr conis.
29	1 40 a.m.	Ibid	= 2nd mag.*	White	0.4 second ...	From $\frac{1}{3}$ (29 Urs Majoris, P Dr conis) to N Dr conis.
29	1 55 a.m.	Ibid	= 3rd mag.*	White	1 second	From α to η Cep
29	2 1 a.m.	Ibid	= 2nd mag.*	White	0.6 second ...	From m Lyncis ι Geminorum.
29	2 5 a.m.	Ibid	= 3rd mag.*	Yellow	0.8 second ...	From κ Geminum to $\frac{1}{2}$ (γ , δ) Cancr.
29	2 46 a.m.	Ibid	= 3rd mag.*	White	0.6 second ...	From k to g Lynx
29	2 59 a.m.	Ibid	= 3rd mag.*	White	0.8 second ...	From τ Ursæ Majoris to n T randi.
29	3 15 a.m.	Ibid	= 3rd mag.*	White	0.8 second ...	From Pollux to Cancr.
29	6 56 p.m.	Paris.....	Very voluminous disk.		3 seconds.....	Centre of path 50 above the horizon, 40° E. from S.
29	7 13 p.m.	Wisbech (Cambridgeshire).	= Sirius	Brilliant yellow.	$2\frac{1}{2}$ seconds ...	From β Aurigæ to $\frac{1}{2}$ (α , γ) Cet
29	8 8 p.m.	Hawkhurst (Kent).	= 2nd mag.*	Bright white..	0.8 second ...	Began at γ Andromedæ.
29	8 16 p.m.	Ibid	= 3rd mag.*	White	0.7 second ...	From ζ Cassiopeiæ to g Lacertæ.
29	8 39 p.m.	Ibid	= 3rd mag.*	White	0.6 second ...	From δ to 36 Dr conis.
29	9 16 p.m.	Ibid	= 2nd mag.*	White	0.8 second ...	From ζ to γ Urs Minoris.
29	9 45 p.m.	Ibid	= 3rd mag.*	White	0.6 second ...	From α Andromedæ to β Pegasi.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
No train or sparks			From Radiant (R_3)	A. S. Herschel.
		From Radiant, D.....	In one hour six meteors	Id.
The train brightened up after the disappearance of the head, and ran back.	25°	W. to E., nearly per- pendicularly down.	Clear evening. Three 2nd mag. meteors and 9 smaller from Cassio- peia, through Perseus.	S. H. Miller.
				W. H. Wood.
Left a streak for 1 second			From Radiant, ξ Leonis	A. S. Herschel.
			From Radiant, K G ...	Id.
			From Radiant, D	Id.
			From Radiant, A_{16}	Id.
			From Radiant, A_{16}	Id.
			From Radiant, K G	Id.
		From Radiant, D	In one hour sixteen me- teors; clear sky.	Id.
			From Radiant, K G ...	Id.
Left a faint streak for half second.			From Radiant, K G ...	Id.
		From Radiant, D	In one hour fifteen me- teors; clear sky.	Id.
Left a large rocket burn- ing very slowly.	30°	S.W. to N.E. Perfectly horizontal.	No report heard	M. Tissot ('Les Mondes,' 1864, Dec. 8).
Left a rocket-like train visible 3 seconds.	50°		The stream of light grew brighter as the meteor advanced.	S. H. Miller.
	3°	Directed from θ Persei	From Radiant, K G ...	A. S. Herschel.
			From Radiant, A_{16}	Id.
		From Radiant, A_{16}	In one hour seven me- teors; clear sky.	Id.
			From Radiant, A_{16}	Id.
		From Radiant, R_3	In one hour nine me- teors; clear sky.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864. Nov. 29	h m s 11 37 30 p.m.	Euston Road Observatory.	= 4th mag.*	Bluish	0.4 second ...	From θ to $\frac{3}{4}^\circ$ above κ Orionis and further.
	29 11 51 p.m.	Ibid	= 4th mag.*	Bluish	0.4 second ...	Began 3° above Orionis.
	30 0 25 a.m.	Ibid	= Sirius	White		Began at 10° above the E. horizon. Disappeared below the horizon.
	30 1 6 a.m.	Hawkhurst (Kent).	= 3rd mag.*	White	0.5 second ...	From $\frac{1}{3}$ (ζ Draconis, α Cephei) 3° beyond $\frac{1}{2}$ (η) Cephei.
	30 1 23 a.m.	Ibid	= 3rd mag.*	White	0.5 second ...	To τ_2 , halfway from B Hydrae.
	30 1 39 a.m.	Ibid	= 3rd mag.*	White	0.7 second ...	From α Leonis Minoris to beyond 57 Ursæ Majoris.
	30 2 5 a.m.	Ibid	= 2nd mag.*	White	0.4 second ...	From $\frac{1}{2}$ (f, e) Leonis Minoris to Ursæ Majoris.
	30 9 52 p.m.	Weston - super - Mare.	= 1st mag.*	Blue	1 second	From α Pegasi to Piscium.
Dec. 1	5 58 p.m.	Hawkhurst (Kent).	= 3rd mag.*	White	1 second	From g to N Draconis.
	2 0 40 a.m.	Ibid	= 3rd mag.*	White	0.6 second ...	From γ to σ Canis
	2 1 13 a.m.	Ibid	= 2nd mag.*	White	0.6 second ...	From γ Geminorum to 126 Tauri.
	2 1 19 a.m.	Ibid	= 3rd mag.*	White	0.6 second ...	Disappeared at Ursæ Majoris.
	2 1 36 a.m.	Ibid	= 3rd mag.*	White	0.4 second ...	From 3 Ursæ Majoris to B.A. 4287 Can. Vena and half as far again.
	2 1 41 a.m.	Ibid	= 3rd mag.*	White	0.4 second ...	From d Leonis Minoris to $\frac{1}{3}$ (μ , Leonis).
	2 6 8 p.m.	Ibid	= 2nd mag.*	White	1 second	From $\frac{1}{2}$ (σ, g) Hornum to θ Andromedæ.
	3 3 30 a.m.	Ibid	Size of full moon...	Nucleus white, tail red.	1 or 2 seconds	Overhead
	4 2 0 a.m. (local time).	Taranaki (New Zealand).	As large as the sun			
	4 6 56 p.m.	Paris	As large as an orange.		4 seconds.....	Began near Capella. Disappeared between α and β Ursæ Majoris.
	5 10 45 p.m.	Hawkhurst (Kent).	= 3rd mag.*	White	1 second	From d to c Camelopardi, and nearly as far again.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Train on whole length of path.				T. Crumplen.
Train on whole length of 10° path.	10°	Towards <i>m</i> Monocerotis	Two others from same Radiant in 10 minutes.	Id.
Globular; left no train		Directed from ζ Leonis	Meteors very plentiful...	Id.
			From Radiant, K G.....	A. S. Herschel.
			From Radiant, L II.....	Id.
Left a streak for 2 seconds			From Radiant, L II.....	Id.
		From Radiant, L II.....	In one hour fourteen meteors; clear sky.	Id.
				W. H. Wood.
		From Radiant, K <i>g</i>	In thirty minutes four meteors; clear sky.	A. S. Herschel.
			From Radiant, K G.....	Id.
			From Radiant, L II.....	Id.
Shortened and crooked light.	3°	Directed from <i>q</i> Camelopardi.	From Radiant, K G.....	Id.
			From Radiant, D.....	Id.
		From Radiant, K G.....	In one hour fifteen meteors; clear sky.	Id.
Left a streak on the middle of its course for 2 secs..			From Radiant, K G.....	Id.
Looked like a fish. The light made all objects distinctly visible.	30° or 40°.	From E. to W.	Foggy and dark morning	Communicated by A. S. Herschel.
Stone fell in the sea two miles from land; another fell at Turakina.			Detonated with a report equal to a hundred cannons. Seen also at Wanganua, eighty miles from Taranaki.	Vienna Acad., 'Sitzungsbericht,' 1865, June 30.
Left a train of many coloured sparks visible for 2 seconds.	30°	S.S.E. to N.N.W.		M. Lartigues (Comptes Rendus).
			From Radiant, D.....	A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1864.	h m s					
Dec. 5	11 0 p.m.	Hawkhurst (Kent).	=2nd mag.*	White, then orange.	1.6 second ...	From β Aurigæ δ Cassiopeiæ.
	5 11 6 p.m.	Ibid	=3rd mag.*	White	0.5 second ...	Began at $\frac{1}{2}$ (κ , Aurigæ.
	5 11 13 p.m.	Ibid	=3rd mag.*	White	0.6 second ...	From δ to ξ D. conis.
	5 11 19 p.m.	Ibid	=3rd mag.*	White	0.6 second ...	From k Lyn to e Ursæ Majoris.
	5 11 30 p.m.	Ibid	=3rd mag.*	White	0.6 second ...	From $\frac{1}{2}$ (ι , η) Aurigæ to ξ Pers.
	5 11 36 p.m.	Ibid	=3rd mag.*	White	0.6 second ...	From $\frac{1}{2}$ (q Can lopardi, D Ur Majoris), ha way to P Can lopardi.
	5 11 39 p.m.	Ibid	=3rd mag.*	White	0.6 second ...	To $\frac{1}{2}$ (h , τ) Ur Majoris, ha way from m Lyncis.
	8 9 49 p.m.	Wisbech (Cambridgeshire).	=Mars	Orange colour	2 seconds.....	From $\frac{1}{2}$ (k , Monocerotis $\frac{1}{2}$ (β , ψ) E dani.
	8 10 17 p.m.	Manchester	=1st mag.*; very bright.		About 4 secs...	Near the stars Ursa Major.
	9 3 45 a.m.	Ibid.....	Brilliant meteor ...		About 2 secs...	In the N.E.
	9 3 50 a.m.	Hawkhurst (Kent).	3 $\times$ Venus.....	White, then pure green.	1.2 second ...	From ζ Cassiope to $\frac{1}{2}$ (σ Honor g Lacertæ).
	9 4 30 a.m.	Ibid.....	=2nd mag.*	White	0.5 second ...	Began at η Virgi
	9 4 31 a.m.	Ibid	=3rd mag.*	White	0.5 second ...	From α Leonis to Hydræ.
	9 5 42 p.m.	Greenwich	=2nd mag.*	Bluish white...	Rapid	Across Lyra to Aquilæ.
	9 9 7 p.m.	Paris	Small, but very brilliant disk.		Less than $\frac{1}{2}$ sec.	Centre of visible path above the horizon, 61° E. fr S.
	13 0 17 a.m.	Manchester	Exhibiting a well-defined disk.	Bluish white...	About 2 secs...	From the centre of Cassiopei chain to midw between α A dromedæ and Cygni.
1865.						
Jan. 1	0 3 30 a.m.	Greenwich	=2nd mag.*; bright.	Bluish white...		From the direct of β Geminoru passed between η and α Leonis
	1 10 17 p.m.	Hawkhurst (Kent).	= 4	White, then orange red.	2 secs., slower at last.	From n Monocerotis to β Can Majoris.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a streak on all its course for $1\frac{1}{2}$ second.			From Radiant, D.....	A. S. Herschel.
.....	3°	Towards β Tauri.....	From Radiant, D.....	Id.
.....			From Radiant, K <i>g</i>	Id.
.....			From Radiant, D.....	Id.
Disappeared suddenly			From Radiant, D.....	Id.
Left a streak for half a second.			From Radiant, D.....	Id.
Left a streak for $1\frac{1}{2}$ second		From Radiant, D	In one hour thirteen meteors; clear sky.	Id.
Left a train divided into two streams.	25°	N. to S., horizontal		Id.
Disappeared suddenly				J. Webb.
It possessed great illuminating power.				'Manchester Guardian.'
Left train or sparks			Threw a faint light on all objects.	A. S. Herschel.
Left train or sparks	10°	Directed from ϵ Canes Venatici.		Id.
Left train or sparks			In one hour twenty-one meteors.	Id.
Left train	20°			W. C. Nash.
Resembling that of Nov. 9.	Very short, inclined.	 Downwards towards the right, 30° from horizontal.	A very short view obtained between the roofs of houses.	M. Tissot, 'Les Mondes.'
Sparks from the head, especially near disappearance. Momentary rain on the whole length of its course.	40°	Perpendicularly down in N.W.	Moonlight; much scud from S.E.	T. Heelis.
Left train		Inclined	Partially clear	W. C. Nash.
Gradually increased to an elongated disk and vanished suddenly; left no streak.				A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Jan. 1	h m 10 34 p.m.	Hawkhurst (Kent).	=3rd mag.*	Yellow	2 seconds.....	From γ Dracon to σ Ursæ Majoris.
2	1 26 a.m.	Ibid	=2nd mag.*	White	0.8 second ...	From $\frac{1}{2}$ (h, v) Ursæ Majoris to Lyncis.
2	1 28 a.m.	Ibid	=3rd mag.*	Dull	0.8 second ...	From b Lyncis to $\frac{1}{2}$ (α, β) Arigæ.
2	1 49 a.m.	Ibid	=3rd mag.*	White	0.5 second ...	From M to Q Camelopardi.
2	1 54 a.m.	Ibid	=3rd mag.*	White	0.6 second ...	Disappeared at Cassiopeiæ.
4	8 25 to 8 45 p.m.	Ibid				
6	10 36 p.m.	Ibid	=3rd mag.*	Yellow	0.8 second ...	From p Camelopardi halfway to σ Ursæ Majoris.
6	10 59 p.m.	Ibid	=2nd mag.*	White	0.7 second ...	From $\frac{1}{2}$ (κ Leonis r Lyncis) to (δ, ϵ) Cancri.
15	11 54 p.m.	Greenwich	=1st mag.*; brilliant.		Less than 1 sec.	From a point a few degrees from Leonis towards α Cancri. Above the moon.
20	8 0 to 8 30 p.m.	Hawkhurst (Kent).	Two small meteors			
22	11 15 p.m.	Weston - super - Mare.	Bright			In the E.
28	11 18 p.m.	Hawkhurst (Kent).	=Sirius	White	1 second	From β to σ Leonis
Feb. 10?	Evening ...	Bangalore, Mysore (S. India).				
10	6 40 p.m.	Greenwich	=Mars	Blue		From the space midway between Ursa Major and Gemini; fell perpendicularly.
17	5 50 p.m.	Auteuil (France)	Fireball		Between 1 and 2 seconds.	In the N.
17	10 4 p.m.	Royal Observatory, Greenwich.	=3rd mag.*	Blue	$\frac{1}{2}$ second	From a point near midway between δ and σ Dracon towards α Cephei.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a momentary train			In one hour four meteors	A. S. Herschel.
			Clear sky; no moon ...	Id.
				Id.
				Id.
	6°	Directed from γ Cephei	In thirty minutes five meteors.	Id.
			No meteors in twenty minutes; clear sky; half moon.	Id.
				Id.
Train or sparks			In thirty minutes two meteors; clear sky.	Id.
Train perceived	15°		Bright moonlight night	W. C. Nash.
Bulbar; increased rapidly; disappeared without bursting.			On the 21st, from 8 ^h to 8 ^h 45 ^m p.m., clear sky; no moon; no meteors.	A. S. Herschel.
				Communicated by W. H. Wood.
Brightest at last; disappeared suddenly.				A. S. Herschel.
			A large meteor fell and burst in the S.S.E. (See a letter from Bangalore, 1865, Feb. 10; Appendix III. 3.)	Communicated by A. S. Herschel.
Train	25°	Perpendicular	Moon full, hazy	W. C. Nash.
Streak 4° or 5° in length; visible several minutes.		Horizontal	Apparent motion; seen also at Sèvres, moving from S. to N., where the streak endured ten minutes.	Villiers du Terage.
Train		Path curved..... δ Draconis. σ Draconis. * *	Faint aurora	W. C. Nash, Arthur Harding.
				
		* α Cephei.		

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Feb. 19	h m s 10 20 p.m.	Slough (Bucks)..	= 1st mag.*	White	1.4 second ...	Began at β Canis Minoris.
	19 10 40 p.m.	Ibid	= 2nd mag.*	White	1 second	From ν Aurigæ to ζ Tauri.
	19 10 50 p.m.	Ibid	= 2nd mag.*	White	1 second	To μ Camelopardi..
	20 10 49 p.m.	Hawkhurst (Kent).	= 2nd mag.*	Yellowish ...	1.1 second ...	From α Tarandi, halfway to θ Persei.
	20 11 30 p.m.	Weston - super - Mare.	= Sirius	Orange	2 seconds.....	From η Draconis to R. A. 313°, N. Decl. 62°.
	20 11 30 30 p.m.	Ibid	= 3rd mag.*			From R. A. 327°, N. Decl. 80°, to R. A. 327°, N. Decl. 60°.
	21 9 12 p.m.	Arbroath (Forfarshire), N. B.	Size of full moon...	Same colour as the moon.	A few seconds	From $\frac{1}{2}$ (Mars Aldebaran) to Betelgeux.
	21 About 9 30 p.m.	Pratis (Fife-shire), N. B.	Size of full moon...	Dazzling white	6 or 8 seconds	Began in the N., and disappeared in the south-west quarter.
	25 0 40 a.m.	Hawkhurst (Kent).	= 3rd mag.*	White	0.9 second ...	To γ Bootis, half-way from m Canum Venaticorum.
	25 0 52 a.m.	Ibid	= 1st mag.*	White	1.3 second ...	From z Bootis to $\frac{1}{2}$ (π Serpentis, ξ Coronæ).
	25 1 6 a.m.	Ibid	= 3rd mag.*	White	0.8 second ...	To π Serpentis, $\frac{3}{4}$ of the way from ζ Bootis.
	25 1 25 a.m.	Ibid	= 3rd mag.*	White	0.8 second ...	From κ Ursæ Majoris to l Telescopii.
	25 10 45 p.m.	Ibid	= 3rd mag.*	Yellow	0.5 second ...	To β Leonis, half-way from l Canum Venaticorum.
	25 11 30 p.m.	Ibid	= 3rd mag.*	Yellow	0.5 second ...	From α to p Canes Venatici.
Mar. 2	7 10 p.m.	Egham (Surrey)	= 1st mag.*	White	1.3 second ...	From β Cancri to Monocerotis.
	17 10 56 p.m.	Hawkhurst (Kent).	= 1st mag.*	White	0.6 second ...	To ϕ , 3° directed from z Virginis.
	17 11 7 p.m.	Ibid	= 1st mag.*	White	2 seconds.....	From $\frac{1}{2}$ (ρ Leonis, f Sextantis) to v_2 Hydræ.
	17 11 12 p.m.	Ibid	= 2nd mag.*	White	0.7 second ...	From $\frac{1}{2}$ (η , σ) Herculis to ι Herculis.
	17 11 14 p.m.	Ibid	= 3rd mag.*	White	0.5 second ...	At κ Cephei.....

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
	16°	Direction from ϕ Lyncis		A. S. Herschel.
				Id.
	4°	Directed from σ Ursæ Majoris.	Lightning frequent in N.E.	Id.
			In one hour two me- teors; clear sky.	Id.
				W. H. Wood.
			Bright display of Au- rora; and again on the 20th of March, from 8 ^h to 12 ^h p.m.	Id.
Drew a long tapering and waving tail, green at the base, and yellow at the point.			Seen also at Innerleithen and Walkerburn.	A. Brown.
Nucleus pear-shaped, tapering to a point two and a half diameters of the moon from the head. The point was red, and threw off bright red sparks.		N.E. to S.W.; hori- zontal.	A vivid light reflected from the snow. A minute after the me- teor disappeared, a long rumbling noise was heard in the north resembling thunder. The noise lasted two minutes, and gradu- ally died away.	J. Anderson.
				A. S. Herschel.
Left a train on the whole course for 1 second.				Id.
				Id.
			In one hour eight me- teors; clear sky.	Id.
				Id.
				Id.
Left no train	15°			Id.
				Id.
				Id.
				Id.
	1°	Almost stationary		Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Mar. 17	h m s 11 15 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0.6 second ..	From ν , halfway ϵ Bootis.
	20 9 10 p.m.	Ibid	=3rd mag.*	Orange	1.3 second ..	From $\frac{1}{2}$ (α , Leonis to θ H dræ.
	25 10 54 p.m.	Ibid	=2nd mag.*	White	1 second	From λ Bootis, $\frac{3}{4}$ the way to σ Can Venatici.
	30 1 35 a.m.	Ibid	=2nd mag.*	White	0.6 second ..	From 2° E. of Serpenti to Ophiuchi.
	30 11 12 p.m.	Ibid	=2nd mag.*	White	0.7 second ..	From $\frac{1}{2}$ (β , θ) to (β , h) Ursæ Majoris.
Apr. 3	0 5 a.m.	Ibid	=3rd mag.*	White	0.4 second ..	From β to $\frac{1}{2}$ (ν , Draconis.
	3 0 5 30 a.m.	Ibid	=3rd mag.*	White	0.4 second ..	From A_2 to t Herculis.
	3 0 39 a.m.	Ibid	=2nd mag.*	White	0.5 second ..	From $\frac{1}{2}$ (γ , Cephei to m Ceti.
	7 2 40 a.m.	Ibid	=3rd mag.*	White	0.4 second ..	From ζ to χ Draconis.
	7 3 4 a.m.	Ibid	=1st mag.*	White	0.4 second ..	Disappeared at Vulpeculæ.
	8 9 49 p.m.	Greenwich	=2nd mag.*	White		Across α Draconis to γ Draconis.
	9 0 5 a.m.	Weston - super - Mare.	=1st mag.*	Bright white..	2 seconds.....	Began 30° above the N.N.E. horizon.
	10 11 30 p.m.	Greenwich				
	12 9 10 p.m.	Weston - super - Mare.	$2 \times$ Venus	Blue	3 seconds.....	From S.E., altitude 40° , to near Cypella.
	15 11 25 p.m.	Greenwich	=2nd mag.*	Blue	Rapid; less than 1 sec.	From the direction of χ to ν Ursæ Majoris.
	19 10 13 1 p.m.	Hawkhurst (Kent).	=3rd mag.*	Orange.....	1.1 second ..	From d Canes Venatici to ζ Leonis.
	20 9 58 p.m.	Brompton (London).	=1st mag.*.....	Bluish white...	0.8 second ..	From 1° above Virginis to $\frac{1}{2}$ above β Leonis.
	20 10 20 57 p.m.	Hawkhurst (Kent).	=3rd mag.*	Orange	0.5 second ..	From γ to κ Ursæ Majoris.
	20 10 21 p.m.	Greenwich	=1st mag.*.....	Bluish white...	Momentary ...	Altitude, Polar distance, azimuth 10° N. of that star; disappeared instantaneously.
	20 10 26 45 p.m.	Hawkhurst (Kent).	=1st mag.*.....	White	0.6 second ..	From α to σ Ursæ Majoris.

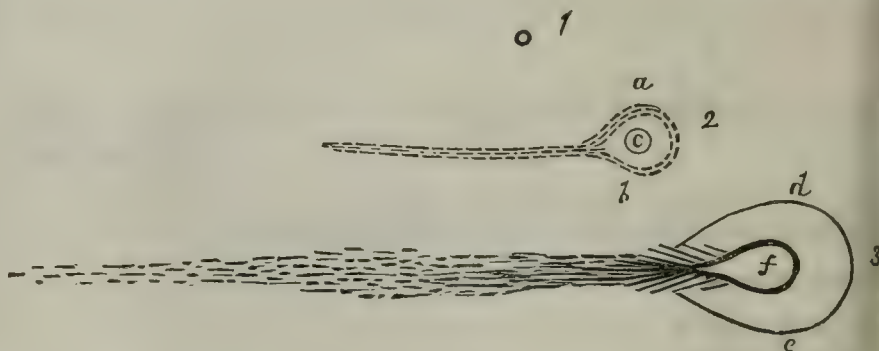
Appearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
.....			In one hour seven me- teors.	A. S. Herschel.
.....			In one hour two me- teors ; clear sky.	Id.
Disappeared by degrees.....				Id.
No train or sparks				Id.
.....				Id.
.....				Id.
.....				Id.
.....			In one hour four me- teors ; clear sky.	Id.
No train or sparks			In thirty minutes one meteor.	Id.
No train or sparks	5°	Directed from α Lyræ.....		Id.
.....			Bright moonlight	W. C. Nash.
Left a train	15°			W. H. Wood.
.....				
.....			A strict watch main- tained for meteors ; NONE seen. A fine bright night.	W. C. Nash.
Star-shaped ; illuminated all objects. Burst with red sparks. Left a bright yellow streak.				Communicated by W. H. Wood.
No train	12°			W. C. Nash.
Left a train for 2 seconds				A. S. Herschel.
Drew off a few sparks and gradually disap- peared.			Well observed ; left a train 5° long.	T. Crumplen.
.....				A. S. Herschel.
Sudden flash	1°			W. C. Nash.
.....				A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Apr. 20	h m s 10 27 p.m.	Greenwich	=4th mag.*	Blue	Less than 1 sec.	Altitude 55°; azimuth about 5° V of preceding meteor; passed almost horizontally across θ Ursæ Majoris.
20	10 35 p.m.	Ibid	=3rd mag.*	Bluish white...	Less than 1 sec.	Altitude, Polar is azimuth 7° E. of that star; fell almost perpendicularly toward the N. horizon.
20	10 45 15 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0.5 second ...	To ν , halfway from θ Ursæ Majoris
20	10 46 p.m.	Greenwich	=1st mag.*	Brilliant white		Between Comæ Berenices and I Canum Venatorum.
20	10 50 p.m.	Bayswater (London).	=2nd mag.*	Yellow		From β Geminorum
20	10 57 p.m.	Greenwich	=1st mag.*	Bright blue ...	Less than 1 sec.	From θ Ursæ Majoris towards ν horizon.
20	10 58 58 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0.9 second ...	From γ Herculis to δ Serpentis.
20	11 15 p.m.	Weston - super - Mare.	=1st mag.*	Orange		From R. A. 252° S. Decl. 5°, to R. A. 247°, S. Decl. 12°.
21	10 15 p.m.	Ibid	=1st mag.*	Blue	0.5 second ...	From R. A. 253° N. Decl. 68°, to R. A. 268°, N. Decl. 52°.
21	11 35 p.m.	Ibid	=3rd mag.*	Blue	1 second	From R. A. 255° N. Decl. 6°, to R. A. 238°, S. Decl. 12°.
21	12 0 p.m.	Ibid	=2nd mag.*	Blue	0.5 second ...	From R. A. 253°, N. Decl. 6°, to R. A. 238°, S. Decl. 5°.
22	0 12 a.m.	Ibid	=3rd mag.*	Blue	0.5 second ...	From R. A. 278° N. Decl. 22°, to R. A. 281°, N. Decl. 2°.
23	0 45 a.m.	Ibid	=1st mag.*	Blue	0.5 second ...	From R. A. 211° N. Decl. 21°, to R. A. 201°, N. Decl. 17°.
23	1 0 a.m.	Ibid	=2nd mag.*	Blue	0.5 second ...	From R. A. 280° N. Decl. 33°, to R. A. 288°, N. Decl. 27°.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Apr. 23	h m 1 8 a.m.	Weston - super - Mare.	=2nd mag.*	Dull yellow ...	2 seconds.....	From R. A. 270°, N. Decl. 37°, to R. A. 290°, N. Decl. 35°.
23	2 5 a.m.	Ibid	=2nd mag.*	Blue	0.5 second ...	From R. A. 151°, N. Decl. 22°, to R. A. 147°, N. Decl. 15°.
23	2 20 a.m.	Ibid	=2nd mag.*	Blue	1 second	From R. A. 119°, N. Decl. 60°, to R. A. 106°, N. Decl. 43°.
25	7 44 p.m.	Hawkhurst (Kent).	=Venus	White	1.5 second ...	From γ Gemino- rum, halfway to θ Canis Majoris.
25	9 3 p.m.	Ibid	=Jupiter	White	Slow motion..	In the S.
25	9 21 p.m.	Ibid	=3rd mag.*	White	1 second	Began at η Virginis
25	9 30 p.m.	Ibid	=1st mag.*	White	1.2 second ...	From ζ to λ Her- culis.
25	9 48 p.m.	Ibid	=2nd mag.*	Yellow	1.8 second ...	From γ Ursæ Mi- noris to ι Ursæ Majoris.
25	11 0 p.m.	Ibid	=1st mag.*	Blue	1 second	From R. A. 190°, N. Decl. 40°, to R. A. 175°, N. Decl. 55°.
25	11 30 p.m.	Frant (Sussex)...	Large	Pale blue	Moved slowly	In the N.E., alti- tude 45°.
26	0 15 a.m.	Weston - super - Mare.	=1st mag.*	Blue	1 second	From R. A. 130°, N. Decl. 50°, to R. A. 110°, N. Decl. 37°.
26	About 10 p.m.	Woodstock (Oxon.).	Nearly = Jupiter ...	White	Remarkably slow motion.	In the S.
26	10 14 p.m.	Weston - super - Mare.	=3rd mag.*	Blue	1 second	From R. A. 68°, N. Decl. 80°, to R. A. 65°, N. Decl. 55°.
27	0 23 a.m.	Ibid	=1st mag.*	Yellow	2 seconds ...	From R. A. 225°, N. Decl. 5°, to R. A. 237°, N. Decl. 8°.
27	10 5 p.m.	Ibid	=Venus	Yellow		From R. A. 192°, N. Decl. 5°, to R. A. 184°, S. Decl. 20°.
27	About 10 15 p.m.	Woodstock (Oxon.).	2 $\times$ Venus	Brownish yellow,	Rapid motion	Near the S.S.W. horizon, altitude 5°.
30	0 41 a.m.	Manchester.....	Considerably ex- ceeding Jupiter, presenting a very sensible disk.	At first red; afterwards bluish white.	From 2 to 2½ seconds.	First seen at a point R. A. 15 ^h 56 ^m , N. Decl. 6°. Disap- peared in R. A. 16 ^h 18 ^m , S. Decl. 19° 0'.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
				W. H. Wood.
				Id.
				Id.
Left a very bright train ...			Seen also overhead at Reading. In forty minutes five meteors; clear sky.	Communicated by A. S. Herschel.
	10° or 12° ..	Descending		Id.
	8°	Directed from ρ Virginis		A. S. Herschel.
Left a train or sparks				Id.
Left a train on all its course for 2 seconds.				Id.
				Id.
Subular; gradually diminished. Left no train.	9°	W. to E.		R. H. Allnatt.
				W. H. Wood.
		W. to E.; horizontal ...	Auroral arch on the 25th, at 9 ^h 15 ^m p.m.	J. H. Abrahall.
				W. H. Wood.
				Id.
Left off red fragments before disappearance.				Id.
Left proceeding two or three degrees across the sky it flared up to twice its proper size and burst.	3° or 4° ...	Horizontal; W. to E....	Left no train; no report heard.	J. H. Abrahall.
Left had two maxima of brightness in its flight, and a tapering train of three or four degrees long.		The path was not straight, but slightly waved.	The train appeared to consist of a number of much smaller meteors.	Jos. Baxendell.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Apr. 30	h m 0 45 a.m.	Weston - super - Mare.	2×Venus	Yellow, red, and green.	5 seconds.....	From R. A. 0°, N. Decl. 58°, to R. A. 315°, N. Decl. 30°. Began precisely at β Cassiopeiæ; well observed.



1. First appearance.

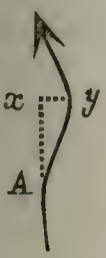
2. Appearance after first quarter of its course: $a b$, expanded diameter; c , contracted diameter.

3. Appearance near the end of its course: $d e = 12'$, diameter of temporary white envelope of the nucleus; f , contracted diameter of the nucleus, green.

30	1 5 a.m.	Ibid	=1st mag.*	Yellow	1 second	From R. A. 0°, N. Decl. 58°, to R. A. 6°, N. Decl. 56°.
30	1 30 a.m.	Ibid	=3rd mag.*	Blue	1 second	From R. A. 20°, N. Decl. 51°, to R. A. 30°, N. Decl. 42°.
May 1	9 40 p.m.	Greenwich	=1st mag.*	Bluish white...	$\frac{1}{2}$ second	From direction of α Ursæ Majoris disappeared near τ Ursæ Majoris.
	1 10 30 p.m.	Ibid	=2nd mag.*	Blue	Less than 1 sec.	From the direction of α Lyræ; disappeared near Cephei.
	1 10 31 p.m.	Ibid	=1st mag.*	Bright blue ...	0.7 second ...	From ν Draconis disappeared a few degrees above Lyræ.
	6 0 16 a.m.	Hawkhurst (Kent).	=2nd mag.*	White	0.7 second ...	From $\frac{1}{2} \gamma$, ω Cephei to f Cuspidis.
	6 11 5 p.m.	Ibid	=4	Orange red ...	4.5 seconds ...	From T Cephei to point midway between 23 and 3 Cygni.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
			Began as a mere luminous point. Grew to equal a 1st mag.* (yellow with yellow tail), in the first quarter of its course. Equal to Venus at half its course (green with red flame-like protuberances behind); tail 18° long, and bright yellow. Expanded and contracted alternately four or five times, in the second half of its course, increasing in brightness until it burst with a flash twice as bright as Venus, faintly illuminating the country. The train remained 3 seconds; 8 or 10 minutes after disappearance, a rumbling noise was heard which lasted 3 seconds.	W. H. Wood.
				Id.
				Id.
Ent train	10° ±	Perpendicular		W. C. Nash.
	8° to 10°			Id.
In	16°	Nearly horizontal		Id.
				A. S. Herschel.
Equal to a 1st mag.*, consisting entirely of a stream of red sparks; and having a flash, or maximum of brightness = 2 1/2 some distance before disappearance.			Three minutes later a report, like that of a cannon at some miles distance was heard.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. May 6	h m 11 53 p.m.	Greenwich	Larger than 1st mag.*		About 1 sec. ..	From a point between α and σ Cygni; flew upward across λ Lyrae, and disappeared 1° or 2° beyond the latter star.
8	0 5 a.m.	Hawkhurst (Kent).	=3rd mag.*	White	0.4 second ...	From ξ Ursæ Majoris to δ Ursæ Majoris.
18	11 20 p.m.	Weston - super - Mare.	=2nd mag.*	Smoky blue...	2 seconds.....	From R. A. 195° N. Decl. 28° , to R. A. 205° , N. Decl. 15° .
24	11 20 p.m.	Manchester	= α Lyrae	Bluish white...	0.9 second ...	From β Cephei to ψ Cygni.
25	0 4 a.m.	Weston - super - Mare.	=3rd, then = 1st mag.*	Pale blue	1.5 second ...	From R. A. 262° S. Decl. 8° , to R. A. 264° , N. Decl. 4° .
25	1 40 a.m.	Ibid	=3rd mag.*	Blue	0.5 second ...	From R. A. 8° N. Decl. 57° , to R. A. 32° , N. Decl. 59° .
25	11 10 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0.5 second ...	To f , halfway from i Canum Venaticorum.
25	11 13 p.m.	Weston - super - Mare.	=1st mag.*	Blue	1.5 second ...	From R. A. 348° N. Decl. 60° , to R. A. 17° , N. Decl. 67° .
June 8	0 8 a.m.	Greenwich	=Venus	Yellowish white.	2 seconds.....	From a point near δ Draconis passed across β Cephei and γ Cassiopeiae, to a point 5° beyond the latter star.
20	10 41 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0.5 second ...	Appeared midway between f Lacertæ and ψ Cygni.
20	10 57 p.m.	Ibid	=3rd mag.*	Yellow	0.7 second ...	From f to κ Pegasi and as far again
20	11 32 p.m.	Ibid	=2nd mag.*	White	1 second	From ϵ Delphini halfway to ϵ Equulei.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
fine train	25°			W. C. Nash.
.....			In thirty minutes one meteor.	A. S. Herschel.
Left a smoky streak 4° in length.				W. H. Wood.
lightly defined disk. Left a momentary train.		Directed from Tarandus	Radiant, N ₈	R. P. Greg.
.....	Ax=4° xy=15'	Rose vertically from Radiant Q ₁ , Q ₂ .	The last 8° of the path were convex towards the west.	W. H. Wood.
				
.....			M ₇ , D w, and D G ₂ this year; occurred in April and May, rather than in May and June.	Id.
train or sparks				A. S. Herschel.
.....				W. H. Wood.
thin	40° ±	Perpendicular	A very brilliant meteor..	W. C. Nash.
train or sparks	6°	Directed from ε Cephei		A. S. Herschel.
train or sparks				Id.
To maxima of brightness in its flight.				Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. June 20	h m s 11 35 p.m.	Hawkhurst (Kent).	=3rd mag.*	Yellow	0.5 second ...	From ϵ to μ Pegasi
July 1	11 50 p.m.	Weston - super - Mare.	=2nd mag.*	Blue	0.5 second ...	$\alpha = \delta =$ From $190^\circ + 58'$ to $193 + 50.$
	2 0 35 $\pm$ a.m.	Ibid	=3rd mag.*	Blue	0.5 second ...	From $168^\circ + 72'$ to $161 + 52.$
	2 1 20 a.m.	Ibid	=3rd mag.*	Blue	1 second ...	From $270^\circ + 30'$ to $245 + 35.$
	9 Night ; 12 0 $\pm$ p.m.	Ibid	Very large	Vari-coloured	Several secs...	From a little W. of N. to some distance E. of N.
15	11 35 p.m.	Warrington (Lancashire).	Very large	Pure white ...		First appeared near α Pegasi, passed very near to Lacertæ, about midway between α and β Cephei and disappeared at a point not far from β Ursæ Minoris.
17	11 4 p.m.	Weston - super - Mare.	=2nd mag.*	Blue	1.5 second ...	$\alpha = \delta =$ From $231^\circ + 12'$ to $228 + 5.$
17	11 20 p.m.	Ibid	=3rd mag.*	Blue	0.25 second ...	From $267^\circ - 3'$ to $267 - 10.$
19	10 26 p.m.	Greenwich	=2nd mag.*	Blue	Less than 1 sec.	From a point midway between Ursæ Major and α Draconis pursued a path for 10° or $12'$ parallel to a line joining δ and Ursæ Majoris and directed towards Capella.
19	10 26 40 p.m.	Lewisham	=2nd mag.*	Blue	3 seconds ...	From β Ursæ Minoris; disappeared near λ Draconis
19	10 30 $\pm$ p.m.	Bristol	Very large	Pale blue	Several secs...	From due S. to E.
19	10 32 p.m.	Greenwich	=Capella.....	Brilliant bluish white.	Less than 1 sec.	From a little below ϵ Ursæ Major to ψ Ursæ Majoris.
28	10 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0.6 second ...	From ϕ , halfway to δ Draconis.
28	10 39 p.m.	Ibid	=2nd mag.*	White, then red.	2.5 seconds ...	From $\frac{1}{2}$ (C, F) Hercules to α Coronæ
28	10 56 p.m.	Ibid	=1st mag.*	White	1.4 second ...	From η Ursæ Majoris to $\frac{1}{2}$ (δ do., Canum Venatorum).

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
o train or sparks				A. S. Herschel.
o train or sparks				W. H. Wood.
o train or sparks				Id.
o train or sparks				Id.
ceedingly luminous, with superb changes of colour.				'Weston-super-Mare Mercury.'
ke a large rocket. The light increased rapidly in the first 10° of its flight. A bluish phosphorescent train was then developed, which continued visible some seconds after the meteor itself had disappeared.	75°		The phosphorescent track terminated about the point where the increase of light terminated.	T. G. Rylands.
train or sparks				W. H. Wood.
train or sparks				Id.
train	10° or 12° ..	Inclined	Very rapid in its motion	W. C. Nash.
in	14°	Inclined		J. P. Trapaud.
eteor of considerable brilliancy; left a tail of golden fire.				'Bristol Daily Post.'
.....	20°		This meteor scintillated considerably, and disappeared very suddenly.	W. C. Nash.
rain or sparks	Very short path.	Nearly stationary		A. S. Herschel.
ed sparks following the nucleus.	38°	Directed from Fomalhaut.		Id.
rain or sparks		From a southern Radiant		Id.

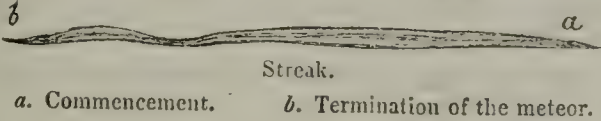
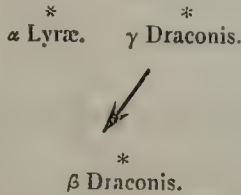
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. July 28	h m 10 58 p.m.	Hawkhurst (Kent).	= 1st mag.* , then twice as bright as γ .	White	1.7 second ...	From $\frac{1}{3}$ (β Aquar. & Equulei) to (α Aquarii, θ Pegasi).
28	11 14 p.m.	Ibid	= 2nd mag.*	Yellow	1.5 second ...	To β Cassiopei halfway from Pegasi.
28	11 17 p.m.	Ibid	= 3rd mag.*	Yellow	0.9 second ...	From θ Pegasi to (β Aquarii, Equulei).
28	11 32 p.m.	Ibid	= 1st mag.*	White, then orange.	1.8 second ...	From $\frac{1}{2}$ (ν , Cygni to $\frac{1}{3}$ (ζ , Cephei.
28	11 35 p.m.	Ibid	> 1st mag.*	White	0.7 second ...	From r Tarandi $\frac{1}{2}$ (ρ , τ) Cephe
29	0 10 a.m.	Ibid	= 2nd mag.*	White	0.5 second ...	Close to δ Dracon
29	0 12 a.m.	Ibid	= 3rd mag.*	Yellow	1.5 second ...	From ξ Cephei to Ursæ Minoris.
29	0 15 a.m.	Ibid	= 1st mag.*	White	0.7 second ...	From γ Dracon to γ Ursæ M. joris.
29	0 20 a.m.	Ibid	= 1st mag.*	White	1 second	From ϵ Honorium α Lacertæ, as far again.
29	0 36 a.m.	Ibid	= 3rd mag.*	Yellow	0.9 second ...	From γ to $\frac{1}{2}$ (θ , Piscium.
29	0 44 a.m.	Ibid	= 2nd mag.*	White	1.3 second ...	From λ Honori to β Cassiopei and half as again.
29	0 52 a.m.	Ibid	= Sirius	White	0.9 second ...	To ϵ Ursæ Major halfway from Camelopardi.
29	0 53 a.m.	Ibid	= 3rd mag.*	White	1 second	To λ Pegasi, $\frac{2}{3}$ the way from Andromedæ.
29	10 10 p.m.	Combe, near Woodstock (Oxon.).	$\frac{2}{3}$ the size of Venus	Pale yellow ...	Slow motion...	Appeared in the at a moderate altitude, and moved toward S.E.
29	10 45 p.m.	Hawkhurst (Kent).	= 3rd mag.*	White	0.5 second ...	From α to Cygni, and far again.
29	10 46 p.m.	Ibid	= 2nd mag.*	White	0.5 second ...	First appeared at Custodis.
29	11 0 p.m.	Ibid	= 2nd mag.*	White	0.8 second ...	From β Cephei π Draconis.
29	11 12 p.m.	Ibid	= 2nd mag.*	Yellow	1.5 second ...	From $\frac{1}{2}$ (κ Cygni, α Cephei), $\frac{1}{2}$ (β , γ) Ur Minoris.
29	11 14 p.m.	Ibid	= 3rd mag.*	White	0.6 second ...	Disappeared at Pegasi.
29	11 16 p.m.	Ibid	= 2nd mag.*	White	0.7 second ...	From α Andromedæ, halfway to Pegasi.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
disappeared with a flash about one degree in length, at which place a train remained 4 secs.	7° or 8° ...	From a southern Radiant		A. S. Herschel.
train or sparks	23°	Directed from Fomalhaut.		Id.
train or sparks				Id.
undulating, throwing off fiery sparks in the last half of its course.	23°	Directed from Fomalhaut.	Undulating motion in the last half of its course.	Id.
conical train remained upon the whole course 2½ seconds.				Id.
train or sparks	No path	Stationary		Id.
train or sparks	26°	Directed from Fomalhaut.		Id.
train or sparks				Id.
streak 2 seconds				Id.
train or sparks		Directed from a southern Radiant.		Id.
train or sparks	21°	Directed from Fomalhaut.		Id.
streak upon the whole path for 3 secs.				Id.
train or sparks			In 2 ^h 30 ^m forty-three meteors: one observer; clear sky; no moon.	Id.
maintained a uniform brightness. Drew a train of sparks.	Long path	Almost horizontal, inclining downwards.	A second at 10 ^h 20 ^m , equally bright; descended vertically. A third appeared at the same hour on the following night.	J. H. Abrahall.
train or sparks				A. S. Herschel.
streak for 2 seconds	4°	Directed from χ Persei.		Id.
streak for 2 seconds				Id.
train or sparks	30°	Directed from Fomalhaut.		Id.
train or sparks	4°	Directed from β Cygni.		Id.
train or sparks				Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. July 29	h m s 11 38 p.m.	Hawkhurst (Kent)	=2nd mag.*	White	0.6 second ...	From K, halfway p Camelopardi
	29 11 39 p.m.	Ibid	=1st mag.*	White	0.8 second ...	From θ Andromedæ, τ Pegasæ, and as far as γ Lyrae
	29 11 50 p.m.	Ibid	=3rd mag.*	White	0.8 second ...	From δ to γ Lyrae
	29 11 52 p.m.	Ibid	=3rd mag.*	White	0.7 second ...	To ι Cephei, $\frac{3}{4}$ the way from Cassiopeiæ.
	29 11 55 p.m.	Ibid	=3rd mag.*	White	0.9 second ...	From α Cassiopeiæ to ν Persei.
	29 11 56 p.m.	Ibid	=2nd mag.*	White	0.8 second ...	From β Cephei to Draconis.
	30 10 25 p.m.	Weston - super - Mare.	=1st mag.*	White	0.5 second ...	$\alpha = \delta =$ From $150^\circ + 44$ to $163 + 35$
	30 11 46 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1.9 second ...	To $\frac{1}{2}$ (α Draconis) ζ Ursæ Majoris $\frac{3}{4}$ of the way from L Camelopardi.
	30 11 56 p.m.	Ibid	=3rd mag.*	White	0.8 second ...	From ζ Cygni halfway to Lacertæ.
	30 12 0 p.m.	Ibid	=3rd mag.*	White	0.5 second ...	To σ Ursæ Majoris $\frac{1}{2}$ of the way from L Camelopardi
	31 0 4 a.m.	Ibid	=3rd mag.*	White	0.8 second ...	To ι Honorium, of the way from α Andromedæ.
	31 0 13 a.m.	Ibid	=3rd mag.*	White	0.6 second ...	To τ , halfway from δ Ursæ Minor and 4° further
	31 0 28 a.m.	Ibid	=2nd mag.*	White	0.7 second ...	From $\frac{1}{2}$ (λ , ν) Honorium to m Lacertæ.
	31 0 34 a.m.	Ibid	=2nd mag.*	White	0.8 second ...	From ϕ to d Pegasæ.
	31 0 39 a.m.	Ibid	=3rd mag.*	White	0.5 second ...	From ω to $\frac{1}{2}$ (ν , ι) Andromedæ.
	31 0 40 a.m.	Ibid	=1st mag.*	White	0.9 second ...	From α to β Andromedæ.
	31 0 41 a.m.	Ibid	=3rd mag.*	White	1 second	From δ Cassiopeiæ to m Custodis.
	31 0 44 a.m.	Ibid	=2nd mag.*	White	1 second	From g to $\frac{1}{2}$ (ι , ν) Draconis.
	31 0 44 30 a.m.	Ibid	=3rd mag.*	Yellow	1.1 second ...	From $\frac{1}{2}$ (λ , ν) Honorium to θ Cassiopeiæ.
Aug. 3	8 40 p.m.	St. Helier's (Jersey).	Large	Red	A few seconds, very brief.	Dropped vertical to the S.E. of E. horizon, from altitude $10^\circ \pm$
	4 11 25 p.m.	Weston - super - Mare.	=Sirius	Bright yellow	0.5 second ...	$\alpha = \delta =$ From $233^\circ + 38$ to $234 + 7$

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
train or sparks				A. S. Herschel.
train or sparks				Id.
train or sparks				Id.
train or sparks				Id.
train or sparks				Id.
train or sparks			In one hour sixteen me- teors: one observer; clear sky; no moon.	Id.
train				W. H. Wood.
a streak on the whole of its course for 2 secs..				A. S. Herschel.
train or sparks				Id.
train or sparks				Id.
train or sparks				Id.
a streak for 2 seconds				Id.
a streak for 2 seconds				Id.
ak 1½ second				Id.
a streak for 1 second				Id.
rain or sparks				Id.
rain or sparks				Id.
rain or sparks				Id.
rain or sparks			In one hour twenty-four meteors: one observer; clear sky; no moon.	Id.
od like a cricket-ball. appeared without bursting.	10°		Seen by several persons at St. Helier's.	Communicated by A. S. Herschel.
nucleus appeared sen- sibly elongated.			Bright moonlight	W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Aug. 5	h m s 9 35 p.m.	St. Malo (France)	=2nd mag.*	White	0·8 second ...	From ϵ Draconis π Herculis.
8	8 55 p.m.	Dax (S. France)	=3rd mag.*	White	0·7 second ...	From μ to Lyræ.
8	9 20 p.m.	Ibid	=3rd mag.*	White	0·9 second ...	From η Cephei η Draconis.
8	9 40 p.m.	Ibid	=2nd mag.*	White	0·7 second ...	From ϵ Ursæ Majoris to $\frac{1}{2}$ Ursæ Majoris Canum Venati rum).
8	9 46 p.m.	Ibid	=2nd mag.*	White	0·7 second ...	From $\frac{1}{2}$ (γ , ϵ) to Cephei.
8	9 47 p.m.	Ibid	= 4	Blue and red..	1·5 second ...	From ψ , across Cephei, to ψ Cyg
8	9 57 p.m.	Ibid	=2nd mag.*	White	0·7 second ...	From γ to β C siopæia.
8	10 20 p.m.	Weston - super - Mare.	> 1st mag.*	Blue	0·5 second ...	$\alpha = \delta$ From $138^\circ + 5$ to $151 + 4$
8	10 42 p.m.	Ibid	> 1st mag.*	Blue	0·5 second ...	
9	11 37 p.m.	Greenwich	=2nd mag.*	Bluish white..	$\frac{1}{2}$ second	Across Draco wards α Lyræ
10	0 to 1 a.m.	Surbiton				
11	9 41 15 p.m.	Greenwich	=4th mag.*	Blue	$\frac{3}{4}$ second	From the direct of μ Bötis a point N. o Bötis.
11	9 48 $\frac{1}{2}$ p.m.	Ibid	=3rd mag.*	Reddish	Less than 1 second.	From a point of γ Bötis t point near Bötis.
11	9 48 10 p.m.	Royal Observa- tory, Green- wich.	=3rd mag.*	Bluish white..	$\frac{1}{2}$ second	From a point n way between and δ Bötis ψ Bötis.
11	9 51 45 p.m.	Ibid	=4th mag.*	Bluish white..	Less than $\frac{1}{2}$ sec.	Between γ and Draconis.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
no train or sparks				A. S. Herschel.
no train or sparks				Id.
no train or sparks				Id.
no train or sparks				Id.
left a streak for 1 second				Id.
the nucleus, surrounded and followed by red sparks. Diminished to a point, and disappeared without bursting. The streak remained visible 15 seconds.	30°	Directed from Perseus.	In the latter part of its course the flight and the streak were twice inflected.	Id.
				
left a streak for 2 seconds			In one hour six meteors: one observer; clear sky; moon nearly full.	Id.
streak visible			Full moonlight; 2nd mag. stars not distinguishable.	W. H. Wood.
.....			Three meteors from 10 ^h to 11 ^h 15 ^m p.m.	Id.
no train	15°			W. C. Nash.
.....			In one hour no meteors seen: sky partially clear; full moon. A terrific storm of lightning and rain before midnight.	T. Crumplen.
no train	8°	Inclined	A fine clear night	Arthur Harding.
no train	10°	Inclined		Id.
no train	7°	Inclined		W. C. Nash.
no train	2°			Id.
				

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Aug. 11	h m s 10 0 p.m.	Weston - super - Mare.	=3rd mag.*	Blue	0.5 second ...	$\alpha = \delta$ From $175^\circ + 5'$ to $191 + 40$ From the vicin of σ Cygni, δ appeared near Cygni.
	11 10 0 5 p.m.	Royal Observa- tory, Green- wich.	=4th mag.*	Bluish white...	Less than 1 sec.	Fell through Equ leus towards horizon.
	11 10 1 5 p.m.	Ibid	=4th mag.* ...	Bluish white...	Rapid motion..	From the direct of β Pegu passed acr Delphinus and Aquilæ to a po 5° beyond latter star.
	11 10 7 30 p.m.	Ibid	=1st mag.*	Blue	More than 1 second.	$\alpha = \delta$ From $0^\circ + 2'$ to $0 + 1$ In N.N.W., altitu 60° , directed wards W.
	11 10 8 p.m.	Weston - super - Mare.	=1st mag.*	White	0.75 second ...	
	11 10 10 30 p.m.	Royal Observa- tory, Green- wich.	=1st mag.*	Bluish white...	1 second	In W., from a po 10° below α Ly passed across Ophiuchi.
	11 10 19 15 p.m.	Ibid	=1st mag.*	Bluish white...	1 second	From the zen in the vicin of η Dracor to a point 1 W. of η U Majoris.
	11 10 19 42 p.m.	Ibid	=1st mag.*	Bluish white...	1 second	From the direc tion of Co Berenices, δ appeared near Böotis.
	11 10 21 30 p.m.	Ibid	=2nd mag.*	Bluish white...	$\frac{1}{2}$ second	From a point below η Ur Majoris towa Arcturus.
	11 10 23 41 p.m.	Ibid	=1st mag.*	Bluish white...	1 second	$\alpha = \delta$ From $37^\circ + 5'$ to $23 + 6'$
	11 10 25 p.m.	Weston - super - Mare.	=2nd mag.*	Blue	0.5 second ...	From a position W. of 12 Can Venaticorum wards the horizon; dis peared at a tude $10^\circ +$.
	11 10 31 30 p.m.	Royal Observa- tory, Green- wich.	=2nd mag.*	Bluish white...	1 second	
	11 10 32 p.m.	Weston - super - Mare.	>1st mag.*	Yellow	1 second	$\alpha = \delta$ From $162^\circ + 58'$ to $170 + 4'$

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
o train or sparks			The nights of the 9th and 10th were overcast.	W. H. Wood.
o train	12°			W. C. Nash.
o train	10°	Perpendicular		Id.
ne train; lasted 1 sec...	25°		A very brilliant meteor..	Id.
o train or sparks				W. H. Wood.
ne train.....				Ernest Jones.
ne train.....				
ne train.....		Almost perpendicularly down.	Very brilliant	W. C. Nash.
ne train.....			Very brilliant	Id.
hall train				Ernest Jones.
ain	12°			W. C. Nash.
ft a train		The meteor ascended apparently.		W. H. Wood.
he train.....				Ernest Jones.
		 * 12 Can. Ven.		
lft a train for 2 seconds				W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Aug. 11	h m s 10 33 34 p.m.	Greenwich	= 1st mag.*	Bluish white...	1 second	From direction γ Persei towards σ Urs Majoris. Cent of path midway between the stars.
11	10 40 p.m.	Weston - super - Mare.	= 1st mag.*	Deep red	1 second	$\alpha = \delta =$ From $212^\circ + 22'$ to $216 + 8$.
11	10 40 15 p.m.	Greenwich	= 3rd mag.*	Blue	More than 1 second.	From the direction of κ Draconis to a point between α Draconis and η Urs Majoris.
11	10 47 15 p.m.	Ibid	= 2nd mag.*	Bluish white...	1 second	From a point between α Urs Majoris and Polaris to a point N of κ Draconis.
11	10 49 p.m.	Weston - super - Mare.	= 2nd mag.*	Blue	1 second	$\alpha = \delta =$ From $195^\circ + 45'$ to $199 + 37$.
11	10 52 p.m.	Ibid	= 3rd mag.*	Blue	1 second	From $24^\circ + 70'$ to $32 + 61$.
11	10 52 p.m.	Greenwich	= 4th mag.*	Blue	$\frac{1}{2}$ second	From the direction of λ Bootis.
11	10 56 p.m.	Weston - super - Mare.	= 2nd mag.*	Red	0.6 second ..	$\alpha = \delta =$ From $205^\circ + 52'$ to $212 + 20$.
11	10 58 p.m.	Ibid	= 1st mag.*	Blue	0.75 second ..	From $190^\circ + 58'$ to $193 + 44$.
11	10 58 45 p.m.	Greenwich	= 3rd mag.*	Blue	Very rapid ..	Passed below ι Draconis from the direction of ι Urs Minoris.
11	11 1 45 p.m.	Ibid	= 1st mag.*	Blue	Greater than 1 second.	From the direction of γ Draconis to a point S. of γ Cygni.
11	11 6 30 p.m.	Ibid	= 3rd mag.*	White	Momentary ...	From a point W. of Polaris.
11	11 10 15 p.m.	Ibid	= 2nd mag.*	Blue	$\frac{1}{2}$ second	From β Cygni in the direction of α Ophiuchi.
11	11 17 45 p.m.	Ibid	= 2nd mag.*	Blue	Slow motion..	Between ξ and ϵ Cygni.
11	11 26 p.m.	Ibid	= 1st mag.*	Bluish white...	1 second	From Cassiopeia shot 20° towards Capella.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Train	10°			W. C. Nash.
Opened in colour and decreased in size.				W. H. Wood.
Train	15°			Arthur Harding.
ht train	25°	Nearly horizontal		Id.
Train or sparks				W. H. Wood.
Train or sparks				Id.
Train	5°	Perpendicular		Arthur Harding.
Train or sparks				W. H. Wood.
Train or sparks			Clear sky from 10 ^h to 11 ^h 15 ^m p.m.; 12 meteors seen: one observer.	Id.
Train	7°	Inclined		Arthur Harding.
Train	20°			Id.
Train	10°	Almost perpendicular...		Id.
Train	12°	Inclined		Id.
		Curved path		Id.
			ξ Cygni. *	
				
	20°	Almost perpendicular...	α Cygni. *	W. C. Nash.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Aug. 11	h m s 11 27 30 p.m.	Greenwich	= 1st mag.*	Blue	1½ second ...	From the direction of β Ursæ Minoris to a point between δ Draconis and γ Ursæ Majoris.
11	11 33 30 p.m.	Ibid	= 1st mag.*	Bluish white...	1 second	From a point above Capella; disappeared 5° below β Aurigæ.
11	11 39 47 p.m.	Ibid	= 3rd mag.*	Bluish white...	Less than 1 sec.	From a point 5° W. of α Ursæ Majoris; passed below δ Ursæ Majoris to a point about 7° below ϵ Ursæ Majoris.
11	11 40 p.m.	Ibid	= 2nd mag.*	Blue	$\frac{3}{4}$ second	From the direction of λ Draconis passed above ϵ Ursæ Majoris to a point below δ Ursæ Majoris.
12	9 10 p.m.	Combe, near Woodstock (Oxon.).	$\frac{3}{4}$ the size of Venus	Pale yellow ...		Fell to very near the S.W. horizon
12	11 7 p.m.	Weston - super - Mare.	= 3rd mag.*	Blue	0.5 second ...	$\alpha = \delta =$ From 242° + 63° to 214 + 51.
12	11 12 p.m.	Ibid	= 2nd mag.*	Blue	0.5 second ...	From 190° + 40° to 193 + 34.
12	11 16 p.m.	Ibid	= 3rd mag.*	Blue	0.25 second ...	From 127° + 53° to 133 + 47.
12	11 21 p.m.	Ibid	= 2nd mag.*	Blue	1 second	From 24° + 70° to 50 + 67.
12	11 25 p.m.	Ibid	= 3rd mag.*	Blue	0.5 second ...	From 265° + 70° to 263 + 51.
12	11 31 p.m.	Greenwich	= 2nd mag.*	Bluish white...	Rapid motion..	In the W.; disappeared near Corona Borealis.
12	11 36 p.m.	Ibid	= 1st mag.*	Bluish	$\frac{1}{2}$ second	From the direction of Sagitta; disappeared near Herculis.
12	11 40 p.m.	Weston - super - Mare.	= 1st mag.*	Blue	0.5 second ...	$\alpha = \delta =$ From 186° + 71° to 190 + 58.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Train	15°	Inclined	A brilliant meteor	Arthur Harding.
Train	10°	Inclined		W. C. Nash.
No train	17°	Inclined		Id.
No train	12°	Inclined		Arthur Harding.
No train or sparks		N.E. to S.W.	A second, nearly as bright, appeared at 10 ^h 15 ^m p.m., falling thus—S. to N. 	J. H. Abrahall.
No train or sparks				W. H. Wood.
No train or sparks				Id.
No train or sparks				Id.
No train or sparks				Id.
No train or sparks				Id.
No train		Almost perpendicular...	Very cloudy.....	W. C. Nash.
light train	15°			Id.
left a train			Clear sky; six meteors from 10 ^h 50 ^m to 11 ^h 50 ^m p.m., for a single observer.	W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Aug. 13	h m s 9 53 p.m.	Tooting, Surrey..	= 1st mag.*	Bluish white...	2 seconds.....	Disappeared near α Lyrae.
13	9 56 p.m.	Ibid	= 1st mag.*	Bluish white...	1 second	From γ Böotis towards γ Serpentis
13	10 2 15 p.m.	Greenwich	= 2nd mag.*	Blue	1 second	From direction of ϵ Ursæ Minoris passed between α and α Draconis.
13	10 6 p.m.	Ibid	= 3rd mag.*	Blue	$\frac{2}{3}$ second	Fell perpendicularly from a point little to the left of Arcturus.
13	10 36 p.m.	Tooting, Surrey..	= 1st mag.*.....	Bluish	1 second	From a point 5' below γ Böotis disappeared near ϵ Böotis.
13	11 30 50 p.m.	Greenwich	= 1st mag.*.....	Bluish white...	1 second	Fell almost perpendicularly in W. from near γ Serpentis.
14	10 23 p.m.	Ibid		Bluish white ..	1 second	From a point little below α Draconis to Draconis.
14	10 40 to 11 p.m.	Combe, near Woodstock (Oxon.).				
17	9 12 p.m.	Greenwich	= 3rd mag.*	Bluish white..	Less than 1 sec.	In the N.N.W. altitude 20°.
17	10 5 p.m.	Argeles (Hautes Pyrenees).	3 or 4 times $\frac{1}{4}$...	White	0.5 second ...	Emerged from cloud at a point midway between ζ and η Ursæ Majoris.
17	10 15 p.m.	Ibid	= 3rd mag.*	Yellow	1.3 second ...	To γ Cephei, $\frac{2}{3}$ of the way from Honoriun.
17	10 25 p.m.	Ibid	= 2nd mag.*	White	1.4 second ...	From γ Pegasi to (ω , ι) Piscium and as far again.
17	11 31 p.m.	Ibid	= 4th mag.*; then $> \alpha$ Lyrae.	Orange, then red.	10-12 seconds	From $\frac{1}{2}$ (κ Cygni, Draconis) to $\frac{1}{2}$ (ϵ K) Camelopardi

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
.....	5°			Ernest Jones.
.....		Lyra. * 		
ne train.....	20°	Nearly horizontal		Id.
o train	5°	Almost perpendicular...		Arthur Harding.
o train		Perpendicular		Id.
ight train	10°			Ernest Jones.
ain	5°	Almost perpendicular...	Bright meteor	W. C. Nash.
ne train.....				Ernest Jones.
.....			Three or four bright meteors seen together. Shooting-stars by no means plentiful. A few bright meteors were also seen on the 13th.	J. II. Abrahall.
o train	12°	Nearly horizontal; E. to W.	Very cloudy; no stars discernible.	W. C. Nash.
eteor not seen. The streak remained visible 15 seconds. Fusiform, fading from the ends towards the centre.	Length of streak 6°.	Direction from E. Drac. to W. conis.	The meteor lighted up the landscape with a bright flash.	A. S. Herschel.
o train or sparks				Id.
eft a streak for 1 second				Id.
qual to a 4th mag.* in the first half of its course; gradually increasing, it drew a train of ruddy sparks 3° in length behind it. In the last 10° of its course it was followed by four or five distinct balls of light, thus—	50°		The meteor and the fragments gradually disappeared. The duration of the flight was from 10 to 12 seconds, well counted immediately after the disappearance of the meteor.	Id.



Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Aug. 17	h m s 11 51 p.m.	Argeles (Hautes Pyrenees).	= 3rd mag.*	White	0.7 second ...	From λ to ϵ Cyg
19	8 40 p.m.	Lac de Gaube (Pyrenees).	= 3rd mag.*	White	0.7 second ...	From ϵ Aquilæ to $\frac{1}{2}$ (δ Aquilæ, Serpenti).
19	9 0 p.m.	Ibid	= 3rd mag.*	White	0.5 second ...	First appeared at Herculis.
21	9 12 18 p.m.	Greenwich	= 2nd mag.*	Blue	1 $\frac{1}{2}$ second ...	From the zenith to a point on the right of Draconis.
22	8 55 30 p.m.	Blackheath	= Venus	Blue	5 seconds ...	From a point near ψ Pegasi to Trianguli.
22	8 59 p.m.	Ibid	= 4th mag.*	White	$\frac{1}{2}$ second	Fell from a point in the vicinity of α Persei.
24	8 27 p.m.	Halton, Hastings (Sussex).	= 1st mag.*	Reddish	3 seconds	Appeared near β Andromedæ, passed 3° under γ Andromedæ, and disappeared close to β Persei.
25	8 58 30 p.m.	Greenwich	= 2nd mag.*	Brilliant blue	Very rapid motion.	From the direction of ψ Cassiopeiæ to a point above ϵ Cassiopeiæ.
25	9 34 p.m.	Ibid	= 1st mag.*	White	1 second	Towards horizon path parallel to line connecting and β Ursæ Majoris.
25	9 35 30 p.m.	Ibid	= 2nd mag.*	Blue	$\frac{3}{4}$ second	From a point 2 left of η Ursæ Majoris, in the direction of Böotis.
25	9 41 p.m.	Ibid	= 4th mag.*	Bluish white..	Very rapid motion.	Passed between ϵ and ι Serpentis towards γ Böotis.
25	10 43 30 p.m.	Ibid	= 3rd mag.*	Blue	1 second	Passed above Coronæ Borealis in the direction of α Serpentis.
26	0 6 a.m.	Ibid	= 2nd mag.*	Blue	$\frac{1}{2}$ second	From direction of α Cephei, disappeared near Draconis.
26	9 10 p.m.	Ibid	= 2nd mag.*	Blue	$\frac{1}{2}$ second	From the direction of η Ursæ Majoris to Böotis.
26	9 35 p.m.	Ibid	= 3rd mag.*	Bluish white..	Rapid motion..	Passed above α Andromedæ towards γ Andromedæ.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
train or sparks				A. S. Herschel.
train or sparks				Id.
train or sparks	6°	Directed from γ Lyrae...		Id.
train	15°	Almost perpendicular...	Slow motion	W. C. Nash.
light train		Nearly horizontal	Burst about 1 second before disappearance, throwing off a shower of sparks.	Arthur Harding.
train	6°	Perpendicular		Id.
light short train				F. Howlett.
train	5°	Inclined		Arthur Harding.
train	10°	α Urs. Maj. *		Id.
train	11°	β Urs. Maj.* Inclined 		Id.
train	6°	Nearly horizontal, to- wards N.		Id.
train	10°	Inclined		Id.
train	5°			W. C. Nash.
train	7°			Id.
train	7°	Inclined		Arthur Harding.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1865. Aug. 26	h m s 9 52 30 p.m.	Greenwich	= Venus	Blue	6 seconds.....	From ϵ Cassiopeiæ disappeared in the neighbourhood of α Persei
26	10 4 p.m.	Ibid	= 3rd mag.*	Blue	$\frac{1}{2}$ second	From direction of β Cephei; disappeared near Coronæ Borealis
26	10 25 p.m.	Ibid	= 4th mag.*	Blue	Very rapid motion.	From the direction of σ Ursæ Majoris to a point above α Draconis
27	8 15 p.m.	Perigueux (S. France).	= 3rd mag.*	White	0.7 second ...	To δ Honorium, of the way from ϵ Cephei.
27	9 5 p.m.	Ibid	= 2nd mag.*	White	0.7 second ...	From θ Cassiopeiæ to $\frac{1}{2}$ (δ Cassiopeiæ, χ Persei).
29	8 38 p.m.	Greenwich	= 1st mag.*.....	White		From a point 50° altitude; 5° right of Polaris to point midway between δ Ursæ Majoris and Draconis.

APPENDIX.

I. METEORS DOUBLY OBSERVED.

(1.) Fireball; 1864, August 31st, 10^h 31^m P.M.

At Exeter, the meteor disappeared at an altitude of 18° in the E.N.E., whilst at Frant in Sussex it appeared to move at an altitude of about 50° in the W., disappearing S.W. From Exeter to Frant, the direct distance is 167 British statute miles, and the distance of the meteor from the earth at disappearance was from forty-five to fifty miles above Chichester, on the coast of Sussex. The character of the data does not permit the investigation to be carried further.

(2.) Fireball; 1864, November 11th, 5^h 35^m P.M.

The meteor was vertical over the west of Auvergne, where it was seen in twilight, and over the valleys of the Lot, Dordogne, and Garonne, in the south of France. It was observed at Hawkhurst, Tunbridge, and West Peckham, near Maidstone, in Kent. The height at disappearance, derived from the English, compared with the French observations, is forty-five miles, between Limoges and Rhodéz. The flight, of more than eighty miles, was accompanied by a brilliant streak, which remained visible several minutes in the twilight. This was nearly horizontal, directed from between N.E. and N.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Light train	20°		Very slow motion	Arthur Harding.
train	5°			W. C. Nash.
train	10°	Inclined		Arthur Harding.
train or sparks				A. S. Herschel.
train or sparks				Id.
train				F. P. Trapaud; Ernest Jones.

(3.) Detonating Meteor; 1864, November 20th, 9^h 50^m P.M.

Disappeared over the North Sea, not far from the mouth of the Humber, off the coast of Lincolnshire. A few minutes after the appearance a report was heard near Uppingham, in Rutlandshire, like the discharge of cannons in the distance. The descriptions at Manchester, Mobberly, Weston-super-Mare, &c., leave no doubt that the meteor was directed from N.E. The detonating fireball which occurred under similar circumstances of time and place, on the 19th of November 1861, was directed from a little E. of S., or very nearly from an opposite direction. In other respects the two meteors resemble one another very closely (*v.* Report, 1862, p. 79).

(4.) Fireball; 1864, December 9th, 3^h 45^m A.M.

The meteor observed at Manchester disappeared N.E. At Hawkhurst, the point of disappearance was 8° above the horizon, N.N.W. The situation of this point is therefore fixed. The flight was directed from the usual radiant of the 6th to the 13th of December, between *Gemini* and *Auriga*, and thus the rest of the flight is easily determined. Path seventy-five miles in 1·3 second, directed from R. A. 95°, N. Decl. 30°. Velocity fifty-eight miles per second. Began ninety miles above Todmorden, in Lancashire. Disappeared thirty miles over York. Although a vivid meteor, no report succeeded its appearance at Manchester.

1865.

(5.) Detonating Meteor; 1865, February 21st, 9^h 25^m P.M.

Over Perthshire, in the neighbourhood of Perth and Stirling. In Fife-shire, a concussion like prolonged thunder was heard in the N. The light reflected from the snow had a very imposing effect. The track of the meteor was from between N. and N.E., with no great inclination towards the earth.

(6.) Detonating Meteor; 1865, April 30th, 0^h 45^m A.M.

Observed at Manchester, and Weston-super-Mare, in Somersetshire (*vide* R. A. S. Monthly Notices, 1865, June 9th).

Path seventy-five miles in two and a half, to five seconds, directed from azimuth 161° W. from S., altitude 12°, near the star *Capella*. Velocity twenty miles per second. Began fifty-two miles above Lichfield (N. lat. 52° 43', W. long. 1° 52'). Disappeared thirty-seven miles above Oxford (N. lat. 51° 44', W. long. 1° 16'). The disappearance took place with a flash, at a distance of eighty-six miles from Weston-super-Mare, where eight or ten minutes afterwards a rumbling report was heard, which lasted a few seconds. Sound, with its ordinary velocity of 1090 feet per second, would take seven minutes to travel the same distance. This meteor belongs to the few whose real tracks are found to lie from the W. to the E. side of the meridian.

II. METEORIC SHOWERS AND THEIR RADIANTS.

(1.) (R. A. S. Monthly Notices, 1864, Dec. 9.)

The radiants T and A G, (of the list contained in the last Report) were conspicuous on the night of the 27th of September 1864. The first, evidently an early appearance of F (No. 49 in the same list), remained in force until the 6th of October, producing swift white meteors, almost entirely dissolving into streaks. A third radiant, O (No. 48 of the same list), was for the first time observed during the occurrence of a considerable shower of ruddy meteors, on the night of the 18th of October 1864. The meteors of this shower are swift and leave voluminous streaks.

(2.) November Star-shower.

The sky was generally cloudy in England on the morning of the 13th of November 1864. The following extract from a letter addressed to the Secretary, Mr. Herschel, proves that the shower was observed at Malta on the morning of the 13th of November, *and that no trace of it remained on the morning of the 14th:—*

S. S. *Ellora*, off Malta, 1864, November 14. "There was a grand display of meteors from midnight to 4^h A.M., all through the watch, the night before last. The watch, an old 'salt,' and an intelligent man, said that it was the grandest shower he had ever seen, and that the whole watch had been looking at them with delight. There were no very striking ones, and none burst. Last night [Sunday night] I watched till 11^h 30^m myself, and told the watch to wake me up if any were seen, and at all events at 5 o'clock. He did so, but reported that not one single one had been visible. The sky was clear enough, but bright moonlight. I looked out a little while, but not a single shot. The watch told me in the morning that there had not been a single one visible till daylight."

(3.) (R. A. S. Monthly Notices, 1865, March 10.)

Two fireballs, on the 9th and 13th of December 1864, were shown to be conformable to G, the general radiant of smaller meteors, which reaches its

maximum about this period. The radiant coincided, as in the previous year, with a point between τ and θ *Geminorum*.

(4.) Star-showers of April, July, and August.

The numbers of meteors recorded on the nights of the 1st–2nd of January, 19th–20th of April, and 10th–11th of August, in the year 1865, were not greater than ordinary. The return of these well-known star-showers was either altogether wanting, especially in January, or very inconsiderable, as in April and August. On the 11th, 12th, 13th, and 14th of August, a few meteors were observed. Several large meteors appeared on the night of the 25th of April 1865. The same was also noticed by Sir John Herschel on the 25th of April 1843 (Proceedings, Brit. Met. Soc. Jan. 1865; p. 314).

During a considerable shower of meteors on the 28th of July 1865, a radiant of novel and interesting character was observed at Hawkhurst. The new radiant was situated close to *Fomalhaut*, and belongs properly to the southern hemisphere. The letter H, omitted by Dr. Heis from his nomenclature of radiant-points, is chosen to designate the shower.

Epoch of the shower; 1865, July 28–9. Position; R. A. 338°, S. Decl. 28°.

The following extract from Sir James C. Ross's 'Voyage to the Southern Seas' (vol. i. p. 98), may be noticed in connexion with this shower.

"H. M. S. *Erebus*, S. lat. 47°, E. long. 97°, 1840, July 28th to 29th. The gale continued all night with a heavy cross sea; there was much lightning to the eastward; *meteors in great numbers were seen darting about in all directions*, and the whole aspect of the sky proclaimed a convulsion or disturbance of the atmosphere of an unusual character."

The position of *Fomalhaut* above the horizon, at the time and place of this observation, on board the 'Erebus' was 17° from the zenith. Only one such meteor was observed at Hawkhurst on the night of the 29th.

(5.) General Radiant-points of shooting-stars (Proceedings, Brit. Met. Soc. 1865, Jan., vol. ii. p. 302).

A list of fifty-six General Radiant-points of shooting-stars, which appeared in the last Report, was founded upon a series of charts prepared by Mr. Greg. The accompanying reduced engravings of meteor tracks contained in three of these charts, illustrate four of the most interesting general radiant-points of shooting-stars occurring in January, February, and March. (Pp. 124, 125.)

The radiant A G₁ (fig. 1.), near *Aldebaran* (No. 3 in the list), embraces the period from Dec. 21 to Feb. 4. A remarkable display of it was first noticed by Mr. Herschel, and by other observers, on the night of the 24th of December 1861. (Report 1862, pp. 40, 80.)

M₃ (fig. 2) represents a radiant between *Leo Minor* and the head of *Leo* (No. 7 in the list), enduring from February 4th to 26th, and having a tendency to a maximum on the 13–15th of the month. It was first noticed by Mr. Greg, Mr. Herschel, and Mr. Wood, in February 1863.

In other showers no tendency to a maximum can be perceived. The radiants M₅, M₆ are of this kind (Nos. 14, 15 in the list), and form a double or twin radiant (fig. 3), advancing, with the time, across the principal stars of *Ursa Major*, from March 3rd to 31st. The same radiant afterwards advances as far as the last star in the Tail of *Ursa Major*, presenting an interesting and well-established instance of the same meteoric shower enduring (from March 3rd to June 2nd) a period of thirteen weeks, and having a radiant advancing throughout the interval in a right line.

(6.) Shooting-stars observed at Münster, 1864-65.

Simultaneous observations by Dr. Heis and his assistants were continued

Fig. 1.

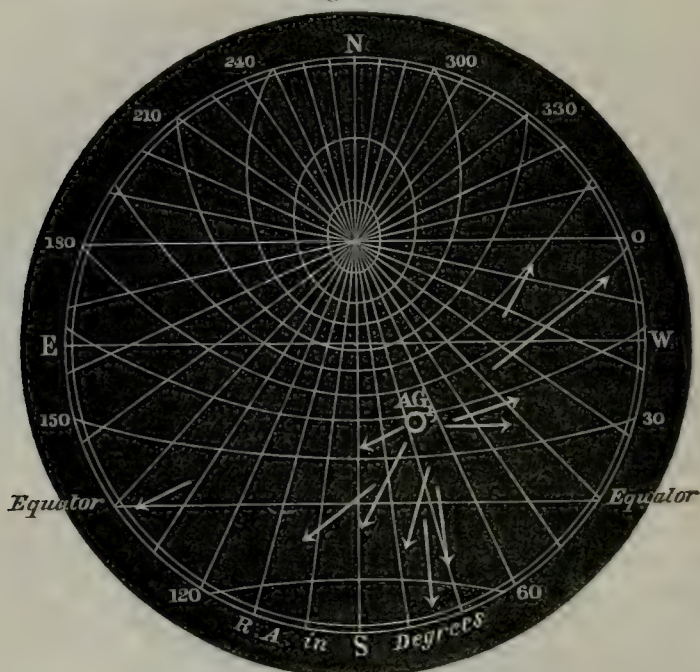
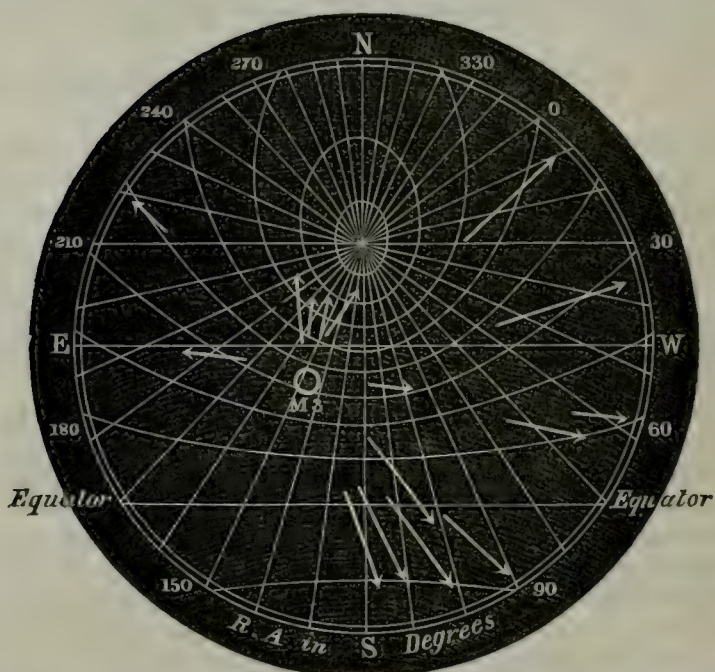


Fig. 2.



from the 27th of July to the 10th of August 1864, and from the 27th of July to the 9th of August 1865, at Münster, Peckeloh, Gaesdonck, Lippstadt, and

Papenburg. The situations of these places, with the exception of Lippstadt, E. long. (from Greenwich) $33^m 20^s.9$, N. lat. $51^\circ 41'$, and Papenburg, E. long.

Fig. 3.



(from Greenwich) $29^m 31^s.0$, N. lat. $53^\circ 4' 30''$, are given in the Report for 1863. The comparative observations given in Tables I. and II. (p. 126) were obtained:—

No. 4. Length of Path ninety-one miles.

No. 5. Length of Path sixty miles.

No. 6. At both stations blue: shot upwards; at Münster from altitude 51° to 71° , at Peckeloh from altitude 45° to 56° .

The radiants observed at Münster in the year 1865 were as follows:—

1865, Apr. 15–29 { $N_s. \alpha = 310^\circ, \delta = +81^\circ$ } in all 38 meteors.
 { $M_s. \alpha = 175^\circ, \delta = +54^\circ$ }

1865, July 27 to Aug. 10.	{	From A	came 26 meteors = 21 per cent
		„ B	„ 43 „ = 35 „
		„ N	„ 5 „ = 4 „
		„ Uncertain radiants	„ 49 „ = 40 „

In all 123 meteors.

III. LARGE METEORS.

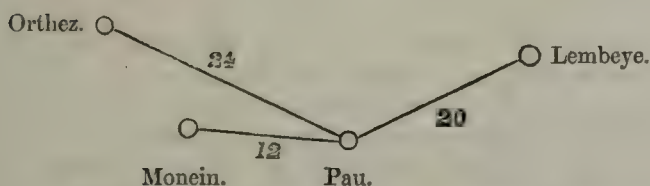
(1.) 1864, September 24th, $12^h 20^m$ (noon). Tarbes (S. France).

The occurrence is described in the 'Comptes Rendus' (for 1864, October 3rd and 10th). The meteor presented the appearance of a ball of fire moving with the rapidity of a flash of lightning, and leaving a cloud of smoke for several minutes. It was seen in broad day as far south as the Balearic Islands, and as far north as Nérac, and Couzon in Creuse. The point of disappearance was nearly over Tarbes, and the flight assigned by M. Le Verrier is forty miles high above the Department of Gers. The following extract of a letter from

a resident at Pau to a relative in England, describes the character of the meteor:—

“Pau, 1864, October 6th. On Saturday, 24th September, the day before I arrived here, M— heard in the house, like many others, a loud report (louder than any cannon). The report was so loud says another, sitting in the English Club, that he thought the windows were smashed in. Another eyewitness here at Pau says he observed a flash of light in a dark cloud, followed immediately afterwards by a tremendous detonation. The enclosed extract from the newspaper will give you the description of it as experienced at Lembeye, twenty miles distant from this (see Catalogue). The detonation was also heard startlingly loud at Orthez, twenty-four miles from this; also at Monein, twelve miles from this, and at Mont-de-Marsan. These places are relatively situated thus (see fig.). At Monein they thought the houses were coming down about their ears. I cannot discover that any meteorite fell.”

Mont-de-Marsan.



(2.) 1864, August 10th, 6^h P.M. Island of Milos (Cyclades).

A detonating meteor appeared over Milos and the Cyclades thirteen minutes before sunset, in full sunlight, leaving a cloud of smoke for more than a quarter of an hour. The meteor was seen at Athens, and the streak was visible sixteen minutes. The heights at appearance and disappearance are estimated by Dr. Julius Schmidt at twenty-five and twenty-three English miles respectively, over Ægina and Paros. The direction was from *Leo*, and the velocity about thirty miles per second. Stones are reported to have fallen upon the island of Polinos, but their meteoric character is not confirmed. The detonation was heard at Milos, where the train of smoke was visible more than a quarter of an hour.

(3.) 1865, February 9th, 6^h 50^m P.M. Salem, Carnatic (S. India).

The following extract of a letter from an English gentleman residing at Bangalore, situated on the high road from Bombay to Madras, was received by Mr. Herschel from a relative in England, to whom the letter was addressed.

“Bangalore, 1865, February 10th. We have had a splendid meteor. I was walking with H—, and at first I thought it was a blue light. It came perpendicularly down; at first it was bright blue, then purple, and at last deep red. It lit up all the country with just the same glare that a blue light makes. Everything could be seen most distinctly. At Salem*, I read in a newspaper it was accompanied by a noise equal to 100 cannons. You could see the trace of it for nearly five minutes after. The moon was up, and

* Salem, in the Carnatic, is eighty miles S.S.E. from Bangalore.

the body itself was larger than it. My boy told me it only comes when a king dies, and curiously enough we hear that the Rajah of Mysore has just died."

IV. METEORITES, SIDERITES, SIDEROLITES. (See also V. (5) to (8).)

(1.) 1863, December 10th, 3^h A.M. Trebizond (Asia Minor).

Three days after the meteoric fall of Tourinnes-la-Grosse, and five days after the largest meteor described in the Catalogue of the last Report, a detonating meteor of very unusual character passed over Samoronitza, near Trebizond. The meteor descended with a report equal to a hundred cannons, into a wood near Inly (twelve miles from Samaronitza), which it set on fire. A thick fall of snow following, a few fragments, only, of doubtful meteoric character, could be recovered on the 6th of March 1864. The real substance of the meteorite appears to have eluded search, from its pulverulent or otherwise easily destructible nature*. Large meteors on the 3rd, 9th, and 13th of December are described in the present Catalogue. They indicate a return of this aërolitic period, rendered famous by the earlier falls of Benares, Wold Cottage, and Weston, and by the recent fall of Montréjeau, near Toulouse, on the 9th of December 1858.

Incendiary meteors have twice been recorded to have taken place upon the 13th of November. The first instance is described in the 'Astronomische Nachrichten' (vol. viii. p. 107),—a meteor which fell near Prague on the 13th of November 1829, and burned the surface of a field brick-red. The second meteor set fire to a barn at Ain, in France, on the 13th of November 1835. The "phosphorescent lines of light" observed in great numbers in the great November shower of 1833, are perhaps meteors of the same description.

Among the municipal records of the town of Ludlow, in Shropshire, there is preserved, in vellum, a roll of bailiffs from the time of Queen Elizabeth. Under the date 1594, occurs the following passage:—

"A greate barne in Lempster [Leominster, Hereford] fired by a comett, and burned 15 dayes."

The occurrence must have created considerable sensation at the time, or it would not have been recorded in such a document; and the writer of the record certainly lived at the time, and in the neighbourhood.

(2.) *Siderites*.

Two large blocks of iron at Western-port, near Melbourne (Victoria), weighing 5 to 6 and 1½ tons respectively, have been examined *in situ* by Dr. Neumayer, who supposes them to be of meteoric origin. The larger is now in the British Museum. A third, weighing 1½ ton, has been transported to Melbourne from the Dandenog hills, sixty miles east of Melbourne, and some miles to the north of Western-port (Vienna Acad. Sitzungsber., 1861, April 18, and June 6).

A portion of metallic iron labelled "native iron" in the Museum at Zürich, has been recognized by Dr. Haidinger as a fragment of the meteoric iron of Steinbach, in Saxony (Vienna Acad. Sitzungsber., 1864, April 28).

(3.) *Siderolites*. (Vienna Acad. Sitzungsber., 1864, May 12.)

A large block of mixed meteoric iron and stone (Siderolite), similar to the

* Vienna Acad. Sitzungsber., 1864, April 28.

meteorite of Hainholtz, has been discovered near the Sierra de Chaco (Chili), in the neighbourhood of the celebrated locality of meteoric iron of Atacama (Comptes Rendus, 1864, Mar. 28).

A new specimen of meteoric iron, weighing 20 cwt., is described at Toconado, 120 miles north of the former locality of Atacama, where the iron is exhausted. A breccia-like fragment of similar iron and stone, found at Copiapo, 300 miles south of Atacama, has been examined by Dr. Haidinger. The included minerals contain a larger proportion of nickel than the iron by which they are surrounded.

(4.) *Äërolites.*

M. Wöhler, who in 1860 analyzed the *äërolites* of Cold-Bokkeveldt, and Kaba (Vienna Acad. Sitzungsber., 1860, July 5), reports the analysis by M. Clöëz, of the meteorites of Orgueil. Besides the usual inorganic constituents, they contain 6 per cent. of a black amorphous organic substance, composed of the organic elements, carbon, hydrogen, and oxygen, in proportions quite similar to those in which they occur in lignite and peat; in other words, a veritable *humus*. M. Wöhler infers from all the facts that wherever meteorites originate, organic matter,—and hence probably, also, organized matter—must have an existence.

(5.) Catalogue of the Collection of Meteorites belonging to R. P. Greg, Esq., Manchester.

The meteorites in this Catalogue are described under a new system of arrangement, based upon those of Shepard and Rose, and altered so as to bring similar meteorites together by their resemblance to different terrestrial minerals. Great uncertainties still exist in the classifications adopted by Shepard, Rose, and Reichenbach, over which this natural system of arrangement in many instances possesses an advantage.

V. PAPERS BEARING ON METEORIC ASTRONOMY.

(1.) Cold days in February and May.

Brandes, at the beginning of the present century, first pointed out the existence of a hesitation in the curve of temperature of the air about the 12th of February. Mädler, in 1834, drew attention to a similar depression of temperature about the 12th of May. Erman, in the year 1840, ascribed these cold days of the year to the obscuration of the sun by the passage of meteorites across its disk. At the opposite extremities of their orbits, one ring of these meteorites furnishes us with the meteors of August, another passes us in November. At these latter periods, M. Petit has shown that the temperature of the air undergoes a small but appreciable elevation. In support of Erman's theory, M. Ch. S. C. Deville cites the mean temperature at Paris of the cold and warm days in question for fifty-seven years from 1806 to 1863 (Comptes Rendus, 1865, Mar. 27). M. Faye remarks upon this mode of accounting for the anomalies in the temperature of the air, that the theory must be received with caution. A slight glance at Mr. Glaisher's Table, showing the adopted mean temperature of every day in the year, as determined from all the thermometrical observations taken at the Royal Observatory, Greenwich, in fifty years, from 1814 to 1863, is sufficient to show that a great break in the continuity of the temperature-curve, perhaps the most remarkable of any in the year, takes place at the end of November,

causing a maximum of temperature on the 3rd of December, which cannot be explained by any regular appearance of meteors at that date.

M. Le Verrier communicates to the Academy of Paris the observation, at Constantinople, of a black body seen to cross the disk of the sun in forty-six minutes, between 9^h and 10^h A.M. (local time), on the 8th of May 1865. The observation adds interest to the former paper on the remarkable variations of temperature in the months of spring (*Comptes Rendus*, 1865, May 29).

(2.) Heights, and Numbers of Meteors (*Am. Journ. Sci.* vol. xxxix. p. 193, and *Mem. Am. Acad.* 1864, Aug. 6).

From the table of heights of meteors contained in the *Am. Journ. Sci.* (vol. xxxviii. p. 135*), Professor Newton estimates the mean height of the centre of the paths of shooting-stars above the earth to be 95·55 kilometres, or not quite sixty miles (see also '*Les Mondes*,' vol. v. p. 756). Their distribution at other altitudes above the earth's surface is plainly indicated by the following Table :—

From 19 to 38 miles (30 kilom. to 60).				Total 114 meteors.	
„ 38 „ 56 „	(60 „ 90).	„ 243 „			
„ 56 „ 75 „	(90 „ 120).	„ 277 „			
„ 75 „ 94 „	(120 „ 150).	„ 106 „			
„ 94 „ 112 „	(150 „ 180).	„ 57 „			

A consideration of 1393 meteors (recorded by about forty observers) shows that the whole number of meteors visible at one place is 50·35 times the number visible within 10° of the zenith, and therefore 50·35 times the number of meteors occurring within this cone. If m represents the hourly number, N the total number visible over the whole earth in the same time, it is shown from the law of distribution in altitude, already stated, that

$$N = 10,460 \times m.$$

Thirty meteors per hour in all the sky, concluded from the careful observations of M. Bouvard (*Comptes Rendus*, xiii. p. 1029), is not too large for the mean value of m . It may therefore be concluded that the average number of meteors traversing the atmosphere *daily*, and large enough to be seen with the naked eye on a dark clear night, is more than *seven and a half millions*.

The number of such meteors traversing a space equal to the sphere of the earth (radius R), at any moment, with an average relative velocity (V), is $116 \cdot 2 \times \frac{R}{V}$ meteors, omitting the effect of the earth's attraction.

The average length of flight of shooting-stars is 12°·6. The mean distance of the centres from the observer is upwards of ninety miles, the average length of path upwards of twenty-five miles, and the average velocity calculated from a mean duration of 0·45 second, is at least forty-eight miles per second. If, however, the average velocity is only thirty miles per second, it follows from this formula that in each volume of the size of the earth, on the track of its orbit about the sun, there are as many as 13,000 meteoroids, large enough to furnish shooting-stars visible to the naked eye.

Of telescopic meteors, it is shown that their numbers are at least forty-fold as great.

* Misprinted vol. xxxvi. in Appendix III. of last Report.

Their average velocity, greater than that of the earth, implies that the meteoroids are not closely grouped about the earth's orbit. That they are grouped according to some law is, however, altogether probable.

1st. They may form a number of rings, like the August ring, cutting or passing near the earth's orbit at many points along its track. The sporadic shooting-stars may be outliers of such rings.

2nd. They may form a disk in or near the plane of the orbits of the planets.

3rd. They may be distributed at random like the orbits of the comets.

According to the first of these suppositions there should be a succession of radiants corresponding to the several rings. Dr. Heis and Mr. R. P. Greg believe that they have detected such a series. Continued observation directed to this end will probably decide whether the meteoroids belong entirely or mostly to rings.

The meteoroids neither belong exclusively, nor even largely to a disk, or to a lenticular-shaped group about the sun, like that which the zodiacal light is often supposed to indicate. The orbits of their rings are not in general circular, as may be inferred from their great velocity, but resemble more the orbits of the comets. Finally, they cannot be regarded as the fragments of former worlds, but may rather be described as the materials from which new worlds are forming. (See pp. 135, 136).

(3.) Streaks, Detonations, &c. of Meteors (Vienna Acad. Sitzungsber., 1864, November 10th).

From a carefully revised catalogue of 2950 meteors in the northern hemisphere, the percentages of detonating, caudate, and aërolitic meteors are separately determined by Dr. Julius Schmidt for every month. The percentage of detonating meteors in August is three times less than in March. The greatest percentage of aërolitic meteors is observed in May, when the percentage of caudate meteors is the least. On the average of the whole year, different coloured shooting-stars are observed in the following proportions:—

White . . . 75·8 per cent.	Red . . . 5·7 per cent.
Yellow .. 15·9 „	Green .. 2·6 „

The average durations in seconds, for the different colours, are as follows:—

White meteors . . . 0·775 sec.	Red meteors . . . 1·905 sec.
Yellow meteors .. 0·921 „	Green meteors .. 3·127 sees.

If the meteor of the 18th of October 1863 is omitted from the thirty-two green meteors, included in the last average, the average duration of the remaining thirty-one green meteors is 2·584 secs.

(4.) Meteorological Observations at the Flagstaff Observatory, Melbourne, Victoria, 1859 to 1862, p. 137.

From the mean of 1428 meteors observed in 668 hours, in three years, Dr. Neumayer concludes the following hourly numbers of meteors at Melbourne, in the different months:—

January 2·1	April 1·4	July 2·7	October 2·9
February 1·9	May 1·9	August 2·7	November 1·7
March 1·7	June 2·8	September 2·5	December 2·8

The following hourly numbers were observed at seasons when meteors were most frequent:—

Between Jan. 25 and 27	5.0	Between Aug. 31 and Sept. 4	4.3
„ June 2 „ 10	4.1	„ Dec. 11 „ „ 13	4.5
„ July 26 „ 31	7.5	„ „ 23 „ „ 25	5.2
„ Aug. 13 „ 18	7.8		

It may be noticed that, at Melbourne, meteors at the latter end of July are nearly as abundant as in August.

(5.) *Inferences and Suggestions in Cosmical and Geological Philosophy. New Theory of the Origin and Formation of Meteorites.* By Professor E. W. Brayley, F.R.S.

Professor Brayley, a Member of the Committee, communicated to the Royal Society on the 23rd of February last (1865), a paper entitled “Inferences and Suggestions in Cosmical and Geological Philosophy,” an abstract of which was read on March 23rd, and appears in the ‘Proceedings’ of the Society, No. 73, vol. xiv. p. 120–129. In this paper a new theory of the origin and formation of meteorites is enunciated.

In the introductory section, the author calls attention to the fact that the position, powers, and functions of the Sun, as the physical centre of the solar system, are peculiar, and in fact unique. The “Primary Induction” from them,—indicating, in his opinion, “the principle of philosophical investigation” which should be applied to the Sun,—is conceived by him to be “That they imply a corresponding uniqueness and peculiarity in its constitution, characterizing also the nature as well as the disposition of the substances of which it essentially consists. But the particular density of the Sun indicates that it actually consists both of ponderable and imponderable matter. The nature of the former as constituting apparently its relatively exterior regions [is] believed to be made known in part by Professor Kirchhoff’s researches in Prismatic Chemistry applied to the Sun, as showing that some of the elementary substances of the Earth exist also in the Sun”*.

The author proceeds to state some of his reasons for believing “that, as a class, the stars are the most ancient objects in the creation, and also (each in its own sphere of action) the origins of the series of physical agencies and processes by which the planets and other classes of heavenly bodies were finally produced and are maintained.” This being admitted, he infers that the original production of ponderable matter takes place in the stars, and in our Sun as one of them—a conception to which he had been led by the preceding and other considerations long before the application of prismatic chemistry to the Sun.

The energy set free in the *condensation* within the Sun, of matter in its highest and most elementary character, of course imponderable, which is conceived by the author to be essential to it, into ponderable matter (an expression which is shown not to be a solecism) and eventually into the metallic vapours which the observations of Kirchhoff and other spectroscopists have discovered in the Sun and other stars, is inferred to be at once the exclusive proximate source of the heat and light and other energies of the Sun, and (in our solar system) the only and universal origin of ponderable matter, the absolute synthesis of which, from its imponderable elements, is thus believed to take place in the Sun.

In the second section, the “Cause and Nature of the Phenomena called the

* Syllabus of Lectures on Astronomical Physics, delivered at the London Institution in 1864, here cited from a revised edition, printed for private use. Lecture V.

Solar spots” are considered. The energy arising from the transition from imponderable into ponderable matter, will in part become, it is here said, the centrifugal or projectile force by which the torrents of matter (finally assuming the gaseous form) so produced, are impelled through the denser envelopes of the Sun, causing the spots and the other phenomena of ebullition of which the photosphere is the scene.

The next subjects of discussion are

The Origin of Meteorites, Series of Physical Processes of which they are the result, and their Functions in Nature.

The vapours of metallic and other elementary matter evolved or discharged in the ebullition of the photosphere of the Sun, partly remain upon the Sun, constituting its atmospheres*, but are principally aggregated into masses of immense magnitude (terrestrially speaking), of the nature of bubbles. Having undergone a certain amount of condensation, these first become visible to us as those particles the collective brightness of which reveals to us the existence of the zodiacal light, and are, in fact, the matter separated from the Sun’s equator by rotation. These particles, termed by the author *meteoritic masses*, are projected from the zodiacal light by the force to which its variable extension is owing, and are further gradually condensed during their passage through the interplanetary spaces into the liquid and solid state, constituting eventually the nuclei of meteors, which are finally precipitated upon the Earth (and doubtless upon the other planets) in the form of METEORITES.

The sudden outburst of light over a solar spot, witnessed on September 1, 1859, by Mr. Carrington and Mr. Hodgson, the author regards as a fact confirmatory of this view, and as having been the consequence or accompaniment of the production, and the transfer with immense rapidity from within to without some exterior region of the Sun, of a meteoritic mass, or more probably of an immense congeries of such masses, enabled by its consisting of ponderable matter to manifest the higher temperature and consequent greater effulgence of the interior regions of the luminary, whence it was originally derived. Certain phenomena before recorded by astronomers, but not yet understood, are probably of the same nature.

The structural characters of meteorites are those of bodies which have been originally condensed from heterogeneous vapours—the mingled vapours of uncombined elementary substances variable in their nature, and requiring different temperatures for their maintenance in the gaseous form, but all existing originally at a very high temperature; and their adequate investigation may afford, as an *experimentum crucis*, an independent confirmation of Kirchhoff’s discovery, and of the truth of the spectrum-analysis of the composition of bodies distant from us in space. They consist, mineralogically, of two groups, meteoric iron and meteoric stones, forming, however, by graduation into each other, as first pointed out by the author many years since, one series of bodies†. The intermediate examples, and indeed most of the stones, are aggregates of earthy matter partly in the crystalline and partly (as Mr. H. C. Sorby has shown‡) in the vitreous state, and distinct portions of metallic iron alloyed with other metals. They are, in fact, always heterogeneous aggregates, in conformity with the origin here assigned to them. While, as a class, meteorites are perfectly distinct from all terrestrial rocks—the presence of metallic iron as a mineral constituent imparting to them, indeed, a character which is perfectly unique—some of their constituent minerals, and all the elementary substances of which they are composed, are such as are found, but differently associated, in the Earth’s crust, although there are many other terrestrial elements which have not yet been discovered in them.

“Ten, or perhaps more, of the elements of the solar atmosphere,” according to Kirchhoff and Ångström, “are also those of meteorites—iron, nickel, cobalt, chromium, and magnesium being characteristically such. But the non-metallic base

* Companion to the Almanac for 1864, p. 46; for 1865, p. 53.

† Annals of Philosophy (January 1824), second series, vol. vii. p. 73; Philosophical Magazine (December 1841), third series, vol. xix. p. 501.

‡ Proc. Roy. Soc., vol. xiii. p. 333. Article V. (7) of this Appendix.

silicon, which, in union with oxygen as silica, is an abundant and equally characteristic element of meteorites, is absent in the Sun, according to our present knowledge, in which also other elements of meteorites, including oxygen itself, are not known to be present".* It cannot be doubted, however, that by the further prosecution of spectrum-analysis, other elements will be discovered in the Sun. It must be remembered also that our knowledge of meteorites is confined to a few only of those which have fallen upon the Earth, and that during a very small space of time, physically speaking, not exceeding a few thousand years, or perhaps even not many centuries; while the synthesis of ponderable matter in the Sun may reasonably be supposed to vary from time to time as to the particular chemical elements produced. A remarkable and instructive fact, in the actual condition of science on this subject, is that the metal iron is now known to be an abundant and characteristic element of the Sun, of Meteorites, and of the Earth.

In harmony with these views on the origin of meteorites is a recorded, but perhaps hitherto unpublished opinion of Sir H. Davy, that they originally consist of the metallic and other combustible bases of the earths and alkalis of which meteoric stones are principally composed. But whether the oxidation of these bases is effected in the Earth's atmosphere, as he also suggested, or whether in some cases, though not in all, oxygen is present in the original assemblage of elementary vapours, and combines with certain bases, and with portions of others, as the condensation proceeds, is a difficult question. The latter theory may be thought to agree better with the entire series of phenomena presented by meteors, and with the constitution of meteorites as a peculiar class of mineral aggregates; but some facts relating to either branch of the subject tend to support the former. Both may be true to a certain extent. The facts, however, that scarcely any oxidation of the iron meteorites has taken place, and that there are no meteorites which consist principally of oxide of iron, while there are some in which metallic iron and earthy matter (oxides) are present in nearly equal proportions, but that even in these no excess of oxide of iron occurs, are opposed to the supposition that meteorites have derived any considerable part of their oxygen from the atmosphere; with which also the existence of sulphide of calcium in certain meteorites is inconsistent.

In what part of space between the zodiacal light and the Earth the final condensation takes place is not at present determinable. It would seem that these masses must retain much of their original heat, and therefore to a great extent an æiriform or vaporous condition (though one of greater density than that in which they left the Sun, or even the zodiacal light, and mingled with liquid or solid matter as just suggested) in the interplanetary spaces where the ether alone exists, and that their entire conversion into a liquid and finally a solid form may not occur until their arrival in a region of positive cold in the vicinity of the Earth or other planets. Mr. Sorby has lately inferred, from the equable manner in which mineral ingredients greatly differing in specific gravity as well as fusibility are mingled in meteorites, that their formation must have taken place in some physical locality where the force of gravitation is small; "that they come either from the outside of a very small planet much less than the moon, or else from the *interior* of a larger planet since broken up"†. The first inference is in perfect accordance with the theory of meteorites announced in this paper; for it is evident that the force of gravity in the original meteoritic masses must be very small, quite inadequate to interfere with the disposition within them, and among one another, of their proximate elements, however discordant in fusibility or specific gravity. It will follow also that the

* Companion to the Almanac for 1865, p. 65.

† Letter to the author [dated July 29, 1864. At the Meeting of the British Association in September 1864, Mr. Sorby stated his inference in a somewhat different form, suggesting "that the fusion and cooling" of metallic meteorites (such as the Pallas Iron) "might have taken place in the metallic centre of small independent bodies, where the specific gravity was *nil*, the meteorites being fragments of such bodies entering subsequently within the earth's attraction, or that each meteorite had been itself a separate small body cooled in space."—Quart. Journ. of Science (Oct. 1864) vol. i. p. 747. The last alternative, it will be seen, is exactly the description of a meteoritic mass as contemplated in this paper. The equable diffusion of proximate elements is equally characteristic of meteoric stones].

final condensation of these vaporous masses cannot take place either very near the Sun or very near the Earth.

According to observations of the author already published*, the iron meteorites, if not certain single meteoric stones (and most probably also the entire nucleus, which in some cases is broken up and falls as a shower of meteorites), have the form (resembling that of the meteors themselves, which is nearly that of a flame) of the solid of least resistance, or of one derived from it, and received in fact from the resistance of a medium they have traversed, but having in general one termination, and sometimes the other also, truncated to a variable extent. This would seem to prove that they must once have been—as individual masses, and not merely as portions of a body of which they originally formed part, nor as to their preexisting materials only—in a fluid or mobile condition. These and other significant circumstances are adduced in the paper as tending to the discrimination of the physical changes by which meteoritic masses are affected prior to their entering the Earth's atmosphere, from those which they afterwards undergo within it, and from its action—the conclusion arrived at being that the solid meteorite is finally left, with a slight alteration in figure, and however greatly reduced in volume, in the approximate actual form—that of a *bubble* elongated by being impelled in a certain direction through a resisting medium—in which, when in a gaseous state, it left the Sun.

The phenomena of luminous meteors (shooting-stars and fireballs) more or less examined by physicists from the latter part of the preceding century (the author having himself endeavoured to elucidate certain characteristic phenomena of fireballs by applying to them the results of modern science†), but which, since the appearance of the persistent meteor-shower in November 1833, have been so assiduously observed and discussed by meteorologists, especially in relation to the periodicity they exhibit, are shown to be entirely conformable to the views of their origin which are enunciated in this paper. The petrological characters of meteorites themselves, as recently investigated by mineralogists‡, together with others before noticed by the author§, are also accounted for by these views, though, with respect to the former, in a very different manner from that hitherto accepted.

The long-continued study of meteorites and of the phenomena which attend their fall, affected by the consideration of the probable synthesis of ponderable matter in the Sun, and—since the conclusions of Kirchhoff have been announced—the special study of solar physics and chemistry, in connexion with both subjects, appear to the author to justify him in entertaining the hope that he may thus have succeeded—by means partly of a new deductive cosmical hypothesis submitted for verification, and partly by uniting, and in some cases newly interpreting, preceding inductions on particular points of their physical history—in effecting at least the approximate solution of the problem of the origin and formation of meteorites, which has been sought by philosophers from the time of the communication to the Royal Society, now sixty-three years since, of Edward Howard's paper, demonstrating their peculiar nature and establishing the reality of their fall||.

In the succeeding section of the paper, relating to the "*Original Formation of the Planets*," it is remarked that the only known phenomenon in which the process of the formation of the Earth as a planet is actually observed, is

* First announced in Lectures on Igneous Meteors and Meteorites given at the Royal Institution in 1839, and at the London Institution in 1841. See English Cyclopædia, Div. Arts and Sciences, METEORS, IGNEOUS or LUMINOUS, vol. v. col. 604.

† See "A Sketch of the Progress of Science respecting Igneous Meteors and Meteorites during the year 1823," read before "the Meteorological Society," May 12, 1824, and published in the Philosophical Magazine (for October of the latter year), first series, vol. lxiv. pp. 288–292; also, Second Supplement to the Penny Cyclopædia, "METEORS, IGNEOUS or LUMINOUS;" and English Cyclopædia, as referred to in the preceding note.

‡ Reichenbach, Haidinger, G. Rose, Maskelyne, Sorby, R. P. Greg.

§ Syllabus of Lectures on Igneous Meteors and Meteorites, delivered at the London Institution in 1841, as reprinted in Phil. Mag., third series, vol. xix. p. 501, with addition, p. 502.

|| Read February 25, 1802; published in the 'Philosophical Transactions' for that year, part 1.

that of the fall of Meteorites upon it, by which its magnitude is augmented, and that by the addition of materials homogeneous with those of its existing elementary constitution, being chiefly those chemical elements which are present in the greatest quantity in the Earth's crust, and seem to be most essential to its constitution. According to the principle of the adequacy of Existing Causes, therefore, we must conclude that the fall of Meteorites is a continuation or a residue of the process of formation of our planet, and that the Earth was originally produced by the aggregation and coalescence of Meteorites, or of greater masses into which they had previously coalesced.

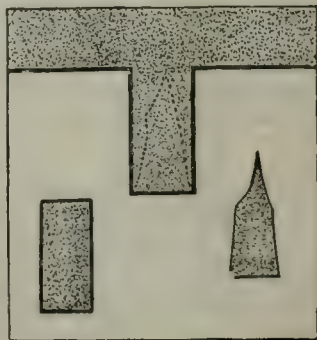
The "*Theory of the Minor Planets*" is briefly considered. All the phenomena they present are regarded as supporting the conclusion that their peculiar relations and community of character are not, as hitherto supposed, effects of their having formerly constituted one heavenly body which has been reduced to fragments, but of their being bodies intrinsically of the same nature, meteoritic masses in fact, in an advanced intermediate state between the condition of meteorites and that of true planets, in process of gradual convergence towards each other, preparatory to their coalescence into one greater planet.

(6.) *On the Microscopical Structure of Crystals.* By H. C. Sorby, F.R.S. &c. (Quart. Journ. Geol. Soc. vol. xiv. pp. 453-500).

From the size of the vacuities seen by the aid of the microscope in certain cavities contained in quartz, felspar, and other crystalline minerals, it is possible to calculate the circumstances of heat and pressure under which the crystals were originally consolidated. On heating the crystals gradually, the vacuous spaces gradually diminish and ultimately disappear. Their dimensions in the natural state are therefore an exact measure of the contraction of the incarcerated fluids in cooling down from the originally high temperature of consolidation. Great liquid pressures at the time of consolidation tend to diminish, and great temperatures to increase the size of the vacuous spaces contained in the cavities in their ultimate or natural state. These fluid cavities exist by millions in every specimen of ordinary quartz, and cause the opacity of this (and the generality of other crystalline minerals) to the passage of the rays of light. Decrepitating crystals are familiar examples of their occurrence among artificial products, such as those of salt, sulphate of potash, nitre, &c. They are indeed of such universal occurrence in crystals, as to form in mineralogy a microscopical test of crystalline aggregation.

By alternate overgrowths and restorations of the crystalline figure in deposition, minute cavities are constantly formed, especially when the deposition is rapid (fig. 2). In these cavities a portion of the flux, or mother-liquor, becomes incarcerated. The foreign substance by which the deposition is for a moment arrested so as to form the cavity is also frequently caught up and confined within the cavity. The cavities are irregular in size, but generally take their figure from the crystalline figure of the mineral. After being cooled down from the temperature of deposition, the cavities exhibit a variety of solid, fluid, and gaseous contents, as well as a vacuity due to the total contraction of the incarcerated fluid. Various examples of cavities in the crystals

Fig. 2.



of minerals are given in the figures at the end of this paper. These consist of, fluid cavities, glass cavities, gas cavities, and stone cavities, according to the different materials by which the cavities were filled in deposition. The coexistence of all of these in the crystalline minerals of igneous rocks, is a certain proof of the combined influence of igneous fusion, aqueous solution and gaseous sublimation in the process of their consolidation. The fluid commonly enclosed in mineral crystals is an aqueous solution of chlorides of potassium and sodium, sulphates of potash, magnesia and lime, and free hydrochloric or sulphuric acid. It forms in some specimens of quartz, fully one per cent. of the total weight of the mineral.

If for various specific reasons a dull red heat (680° F.) is adopted as the ordinary temperature of consolidation of the igneous rocks, lavas, trachytes, and granites, a fluid pressure of 4000 feet of superincumbent rock would exactly equipoise the vapour-tension at this temperature of the saline fluids. If a greater liquid pressure prevailed than this, which would generally be the case, no vacuity could be formed within the cavities, until by cooling and contraction the liquid pressure within them should decrease so far as not to exceed the vapour-tension of the fluid. If p be the excess of pressure at the time of consolidation at a temperature of 680° F., measured in feet of superincumbent rock, v the observed proportion of vacuity to liquid volume in the cavities at 0° C. (32° F.), the equation between these quantities, derived from the best data of the elasticity of water, and of its vapour, in combination with saline substances, is briefly

[illegible]

If P be the total pressure of superincumbent rock, including the vapour-tension at 680° F. at the time of consolidation,

$$P=4000+28,385(0.3-v).$$

The contraction of the fluids can be observed with considerable accuracy by the aid of the microscope, in cavities that are equiaxial, or else (as in figs. 50, 101) in such as are long and slender, or very thin and flat. The value of v varies in different specimens of quartz from 0.04 to 0.25, and from these the following Table was calculated of depths at which a variety of igneous rocks submitted to the microscope were probably consolidated:—

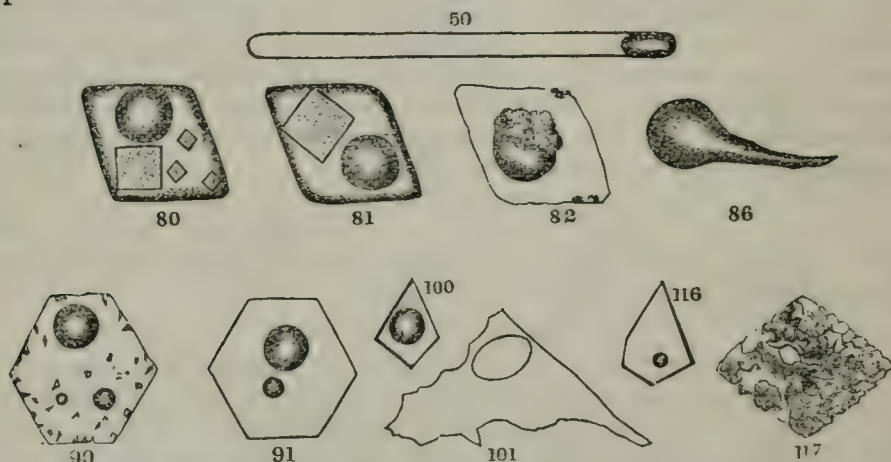
	Depth in feet.
Trachyte of Ponza	4,000
Elvan of Gwennap	18,100
Granite at St. Austell	32,400
Mean of Cornish Elyans	40,300
More recent veins of Aberdeen Granite	42,000
Mean of Cornish Granites	50,000
Elvan, at Swanpool, near Falmouth	53,900
Granite from Ding-Dong Mine, Penzance	63,600
Mean of the Highland Porphyry Dykes	69,000
Exterior of the main mass of the Aberdeen Granite	69,000
Mean of the Highland Granites	76,000
Centre of the main mass of the Aberdeen Granite	78,000

Mean of all the igneous rocks 49,692

The greater depths of the Aberdeenshire granites over those of Cornwall (figs. 100, 116), shown in this Table, are conformable to general opinions concerning these granites, derived from purely geological considerations.

The mean depth of consolidation of all the igneous or gneissoid rocks of the Table is nearly 50,000 feet, and a rate of increase of 1° in 85 feet, according to the information of Mr. R. Hunt, observed in descending to the bottom of the deepest mines in England, would require a temperature of 680° F. (adopted in calculating this Table) at a depth below the surface of 53,500 feet, very nearly in accordance with the original supposition.

The molten lava of Mount Teneriffe can hardly be supposed to have an actual depth less than that of 30,000 feet. The height of the mountain and the depth of the ocean near its western side, indeed, amount together to 28,000 feet, and if the lava have any lateral extension to a moderate distance in the same direction, a few thousand feet of rock must necessarily intervene between its surface and the ocean-bed. The igneous rocks, hitherto examined in the microscope, appear therefore to have been consolidated at depths commensurate with those of modern lavas. In other words, granites, trachytes, and gneissoid rocks are unerupted lavas of older volcanoes, consolidated by loss of temperature, and variously protruded to the surface along with the superincumbent strata.



Explanations of the Figures. The sign of multiplication indicates the amplifying power employed; in linear measure.

Fig. 2. (p. 136). A portion of the growing edge of a crystal of chloride of sodium, $\times 200$: showing how the fluid cavities are formed. The shaded part represents the concentrated solution entering into a deep notch formed by the irregular growth of the crystal. The notch may be enclosed by a plane surface, or, as shown by the dotted line, by the further growth of the crystal, and cavities like those upon the right or left of the figure will be the result.

Fig. 50. A fluid-cavity.

Fig. 80. A fluid-cavity in the nepheline of a block ejected from Vesuvius, $\times 1000$.

Figs. 81, 82. The cavity, fig. 80, after having been subjected to a more or less bright red-heat.

Fig. 86. A gas-cavity in the nepheline of a block ejected from Vesuvius, in a natural state, $\times 1000$.

Fig. 90. A glass-cavity in the nepheline of a block ejected from Vesuvius, $\times 1200$.

Fig. 91. The cavity, fig. 90, after having been subjected to a bright red heat.

Figs. 100, 101. Fluid-cavities in the quartz of a Trachyte from Ponza; 100, $\times 2000$; 101, $\times 800$.

Fig. 116. A fluid-cavity in the quartz of the main mass of granite at Aberdeen, $\times 2000$.

Fig. 117. A stone-cavity in the quartz of the granite at St. Austell, Cornwall, $\times 1000$.

(7.) *On the Microscopical Structure of METEORITES.*

By H. C. Sorby, F.R.S., &c.

(From the Proceedings of the Royal Society, June 16th, 1864.)

"For some time past I have endeavoured to apply to the study of meteorites the principles I have made use of in the investigation of terrestrial rocks, as described in my various papers, and especially in that on the microscopical structure of crystals (Quart. Journ. Geol. Soc. 1858, vol. xiv. p. 453. See the preceding Article). I therein showed that the presence in crystals of 'fluid-, glass-, stone-, or gas-cavities' enables us to determine in a very satisfactory manner under what conditions the crystals were formed. There are also other methods of inquiry still requiring much investigation, and a number of experiments must be made which will occupy much time; yet, not wishing to postpone the publication of certain facts, I purpose now to give a short account of them, to be extended and completed on a subsequent occasion*.

"In the first place it is important to remark that the olivine of meteorites contains most excellent 'glass-cavities,' similar to those in the olivine of lavas, thus proving that the material was at one time in a state of igneous fusion. The olivine also contains 'gas-cavities,' like those so common in volcanic minerals, thus indicating the presence of some gas or vapour (Aussun, Parnallee). To see these cavities distinctly, a carefully prepared thin section, and a magnifying power of several hundreds are required. The vitreous substance found in the cavities is also met with outside and amongst the crystals, in such a manner as to show that it is the uncrystalline residue of the material in which they were formed (Mező-Madaras, Parnallee). It is of a claret or brownish colour, and possesses the characteristic structure and optical properties of artificial glasses. Some isolated portions of meteorites have also a structure very similar to that of stony lavas, where the shape and mutual relations of the crystals to each other prove that they were formed *in situ*, on solidification. Possibly some entire meteorites should be considered to possess this peculiarity (Stannern, New Concord), but the evidence is by no means conclusive, and what crystallization has taken place *in situ* may have been a secondary result; whilst in others the constituent particles have all the characters of broken fragments (L'Aigle). This sometimes gives rise to a structure remarkably like that of consolidated volcanic ashes, so much, indeed, that I have specimens which, at first sight, might readily be mistaken for sections of meteorites. It would therefore appear that, after the material of the meteorites was melted, a considerable portion was broken up into small fragments, subsequently collected together, and more or less consolidated by mechanical and chemical actions, amongst which must be classed a segregation of iron, either in the metallic state or in combination with other substances. Apparently this breaking up occurred in some cases when the melted matter had become crystalline, but in others the forms of the particles lead me to conclude that it was broken up into detached globules whilst still melted (Mező-Madaras, Parnallee). This seems to have been the origin of some of the round grains met with in meteorites; for they occasionally still contain a considerable amount of glass, and the crystals which have been formed in it are arranged in groups, radiating from one or more points on the external surface, in such a manner as to indicate that they were developed after the fragments had acquired their present spheroidal shape (Aussun, &c.). In this they differ most characteristically from the general type of concretionary globules found in terrestrial rocks, in which they radiate from the centre; the only case that I know at all analogous being that of certain oolitic grains in the Kelloways rock at Scarborough, which have undergone a secondary crystallization. These facts are all quite independent of the fused black crust.

* "The names given thus (Stannern) indicate what meteorites I more particularly refer to in proof of the various facts previously stated.

"Some of the minerals in meteorites, usually considered to be the same as those in volcanic rocks, have yet very characteristic differences in structure (Stannern), which I shall describe at greater length on a future occasion. I will then also give a full account of the microscopical structure of meteoric iron as compared with that produced by various artificial processes, showing that under certain conditions the latter may be obtained so as to resemble very closely some varieties of meteoric origin (Newstead, &c.).

"There are thus certain peculiarities in physical structure which connect meteorites with volcanic rocks, and at the same time others in which they differ most characteristically,—facts which I think must be borne in mind, not only in forming a conclusion as to the origin of meteorites, but also in attempting to explain volcanic action in general. The discussion of such questions, however, should, I think, be deferred until a more complete account can be given of all the data on which these conclusions are founded."

(8.) *Note on the preceding Articles (5) and (7).* By Professor Brayley.

My friend Mr. Sorby, having resumed his microscopical investigation of the structure of meteorites, privately printed and circulated a note, dated July 1865, "On the Physical History of Meteorites," in which he gives in a concise form what he terms "a provisional theory" of their formation, announcing also his intention to "describe the facts upon which it is founded," and discuss the "objections to this and other theories in a [future] communication to the Royal Society." The reception of an impression of this note from Mr. Sorby occasioned me to print, also for private circulation, a comparison of the physical history of meteorites as inferred in my own communication to the Royal Society, as above (p. 132), with that inferred by him from his new observations of their microscopical structure. This was placed in the hands of the officers of the Association, at the Meeting at Birmingham, but too late to allow of its being read at any of the sectional meetings. The present article is a brief abstract of it, with some additions.

Of the two most important results relative to the origin and formation of meteorites obtained by Mr. Sorby, the first is stated, in his note, as follows:—

"A most careful study of their microscopical structure leads me to conclude that their constituents were originally at such a high temperature that they were in a state of vapour, like that in which many now occur in the atmosphere of the Sun, as proved by the black lines in the solar spectrum."

As original induction from observed facts, this is in reality a verification, to an important extent, of the hypothesis of the origin and formation of meteorites announced in my paper. But I had already arrived at, and made public in that paper, exactly the same conclusions, with the addition that this vapour had actually been a part of the same mass, and was identical in origin, with that forming the atmosphere of the Sun, constituted as we believe it to be, on the authority of Kirchhoff and the other spectroscopists who have continued and repeated his researches (p. 132).

Some of Mr. Sorby's subsequent conclusions are also closely parallel to my own. "On cooling," he continues, "this vapour condensed into a sort of cometary cloud, which was in a state of great commotion." This "cometary cloud" is manifestly identical in nature with the bubbles or volumes of gaseous matter consisting of the vapours of metallic and other elementary substances, which, having undergone a certain amount of condensation, are conceived by me to be projected from the Sun and through the Zodiacal Light; and their gaseous contents having constituted, according to my views, the torrents causing the phenomena termed the solar-spots, in the stupendous ebullition of the photosphere, they must necessarily be "in a state of great commotion," which would be retained long after their projection from the Sun.

Mr. Sorby finally concludes "provisionally that meteorites are records of the existence in planetary space of physical conditions more or less similar to those now confined to the immediate neighbourhood of the Sun," at a remote cosmical period; a conclusion which he identifies with "a modified nebular hypothesis."

These physical conditions of planetary space at a former period are those which I attribute to the interior regions of the Zodiacal Light as existing now, and of the actual nature of which meteorites may be regarded as perpetual records. But I believe it may be shown, by a strict process of reasoning, that one of the necessary

results of the "uniqueness and peculiarity of the position, powers, and functions of the Sun, as the physical centre of the solar system," is, that such conditions must in the nature of things have been from the beginning, and must ever be, confined to it and its immediate vicinity; that they never have existed, and cannot exist, anywhere else in the solar system, or in the space which it now occupies. Of the presence of the conditions requisite for the genesis of meteorites within, upon, and immediately around the Sun, we have actual and ample evidence, quite independent of that which may be derivable from meteorites themselves. But all that can be said in support of the notion that such conditions could ever extend to distances from the Sun comparable to those of the planets, is to adduce the very facts to account for which that notion is brought forward, or refer to what are supposed to be the probabilities of the "nebular hypothesis" hitherto unverified.

I deem myself justified in affirming that Mr. Sorby, by his microscopical observations of the structure of meteorites, has verified the hypothesis of their origin and formation which has been stated in my "Inferences and Suggestions" through a great part of their genetic history,—to the extent that is, of their condensation from separate volumes or masses (believed to be originally solar bubbles) of æriform matter, consisting of the mingled vapours of their chemical elements, at a very high temperature, in intense commotion, and existing, or having existed, in planetary space somewhere between the Sun and the Earth*.

The second most important result of Mr. Sorby's investigation, is that many meteorites have been subjected to a metamorphic action.

"The particles of the cometary cloud," he says, "moving with great velocity, were often broken by collision. After collecting together to form larger masses, heat, generated by mutual impact, or that existing in other parts of space through which they moved, gave rise to a sensible amount of metamorphism. In some few cases, when the whole mass was fused, all evidence of a previous history has been obliterated; and on solidification a structure has been produced quite similar to that of terrestrial volcanic rocks."

The basaltic character of meteoric stones which Dr. Haidinger and Mr. A. S. Herschel have adduced in support of their conclusion, that they must have been fragments of true planets previously existing, together with the mineral constitution which has led the former inquirer as well as Mr. R. P. Greg to regard them as unerupted lavas, are manifestly the results of the metamorphism which some have undergone, for the discovery of which, thus announced, science is indebted to Mr. Sorby. That while existing as meteoritic masses resulting from the condensation of solar bubbles and froth, and prior to their coalescence into planetary bodies, or becoming the nuclei of meteors, meteorites had undergone metamorphism, or that any which had actually fallen upon the Earth had suffered that process, had never occurred to me; although I had been indebted to Mr. Sorby's kindness and liberality for an opportunity of examining his series of sections of meteorites prepared for the microscope, before my paper was communicated to the Royal Society. This discovery has removed an ambiguity, which from the time when the resemblance of certain meteorites to volcanic rocks was distinctly recognized, has led to continued misapprehension of the nature of meteorites in general, and of their genetic history. From this I had been myself preserved only by the conviction, that a group or series of mineral aggregates possessing the unique character that nearly all its terms, even those principally composed of oxides, contained iron in the metallic state, while some were entirely devoid of oxygen, consisting exclusively of iron and other metals, together with uncombined carbon, and also sulphur and phosphorus (if not silicon) united merely with portions of those metals, could not have had the same origin with another group, volcanic rocks, which are characteristically the results of oxidation, all their proximate constituents being oxides, whether simple or compound. It was as evident at least that certain meteoric rocks were genetically independent of the presence of oxygen, as that all volcanic rocks were essentially due to its action; while the meteorites devoid of oxygen were mani-

* The four paragraphs which terminate here have already appeared in an article on the physical constitution and functions of the Sun, in the 'Companion to the Almanac' for 1866, in sequence of two others contained in the same work for the two preceding years. In the same article are some further considerations (also derived from my privately printed paper) relative to the meteoritic constitution and physical circumstances of the Zodiacal Light.

festly as typically meteorites as those principally composed of oxides, and must have originated in the same cosmical process. Metamorphosis alone, it is evident, could not have converted meteorites devoid of oxygen into those which consist chiefly of oxides, though a process of reduction resulting from the same cause, and going on at the same time, might have converted the latter class into bodies resembling the former. But the two groups—or rather the extreme terms of the series of Meteoric Rocks—differ so greatly in their chemical composition, that the oxidation of the unoxidated group would not result in the production of the oxidated, nor would the reduction of the latter have produced the former. The meteoric irons must have originated either from the condensation of vapour in which oxygen was not present, or under conditions in which its activity was more or less controlled. It is highly probable, however, that the most perfectly stony meteorites, those most nearly resembling Volcanic Rocks, and in which the smallest amount of metallic iron occurs, have resulted from a combined process of metamorphosis and oxidation. All this is perfectly consistent with my inference recently advanced, that the production of terrestrial hypogene rocks “would be one of the final results of the Earth’s formation by the coalescence of meteoritic masses;” an inference which is I believe original, and the announcement of which was made previously to Mr. Sorby’s discovery that some fallen meteorites have already undergone metamorphic action.

Report on Dredging the Coast of Aberdeenshire.
By the REV. WALTER GREGOR, and ROBERT DAWSON.

THE Committee appointed by the British Association for the Advancement of Science, for dredging the coast of Aberdeenshire, having engaged a smack belonging to Banff, left that port on Tuesday, the 4th of July. The voyage was continued till they found themselves off Girdleness, the southern point of the Aberdeenshire coast. On Wednesday evening the distance from land was about forty miles, and the depth of water was thirty-eight fathoms, with a bottom of shingle and broken shells. The vessel was on the bank known as “The Long Forties.” The dredgings from this spot yielded no Arctic fossil shells, although they were found in abundance on a smaller bank, which lies nearer the shore, and at a distance of from eight to fifteen miles from land. There were, however, brought up, in a decayed state, the four most common littoral species, viz. *Littorina rudis*, *Purpura lapillus*, *Solen siliqua*, and *Mytilus edulis*, the last being, with one exception, the small shore variety.

The Committee then sailed in and dredged in depths of forty fathoms with a bottom of sand, forty-eight fathoms with a similar bottom, and fifty-seven fathoms with a bottom of mud, shingle, and the concreted sand-tubes of a species of *Sabellaria*, without finding any fossil shells. They continued their course N.W. till they sighted the Buchanness Light-House on Thursday evening. On Friday, when about ten miles from land, the dredges were put out in fifty-four fathoms, with a bottom of mud and shells. The vessel was then steered N. by E. for two hours. The dredges were again let down in forty-five fathoms, when fossil shells came up in abundance. During the day there was a thick fog, accompanied by torrents of rain. By evening it was blowing a strong breeze, and the Committee were obliged to make for Peterhead Bay. The weather continued unfavourable till Monday, when the Committee again sailed. It being almost a dead calm, little way was made, and it was late in the afternoon before it was deemed expedient to throw the dredges. About seven miles from land the dredges were let down in forty fathoms, when large quantities of fossil shells came up. During the night the vessel continued her course N. by E. from Buchanness, and by morning (Tuesday, 11th July) was twenty-five miles from land. Here the depth was

found to be 65 fathoms, and the bottom mud. Round this spot the dredging was carried on for the day. During the afternoon a breeze sprang up, and the working of the dredges became impossible. There was nothing for the Committee but to return to Peterhead Bay.

The portion of the coast explored extends from Girdleness, the southern extremity of Aberdeenshire, to a few miles north of Peterhead. There thus remains undredged a distance of rather more than ten miles on the east coast, and of twelve miles on the north coast, at the entrance of the Moray Firth, from Kinnaird to the Banffshire coast. The Committee regret that the weather was not more favourable, as they have every reason to think they would have been able to accomplish the dredging of the whole of the Aberdeenshire coast, and thus have had the means of presenting to the Association a much fuller report than the one now submitted.

From the soundings, and the nature of the dredgings, the following conclusions may be drawn:—The sea gradually deepens for a distance of eight to fifteen miles, when a bank covered with Arctic fossil shells occurs. The depth again goes on increasing, till the bank called “The Long Forties” is reached. From this bank no Arctic fossil shells were obtained but decayed littoral species. The inner bank is, no doubt, composed of drift. It is highly probable that the outer bank (“The Long Forties”) was at one period an island, or the shore of a continent, which has since been submerged under the sea.

It may be remarked that, along with the littoral species dredged from “The Long Forties,” there came up a valve of the West Indian shell, *Lucina pensylvanica*.

On referring to the Report of the Committee for dredging the North and East Coasts of Scotland, laid before the meeting of the Association in 1862, it will be found that the number of Mollusca collected by Mr. Dawson on the Aberdeenshire coast amounted to 223 species, arranged as follows:—

Gasteropoda Prosobranchiata	110
—— Opisthobranchiata	11
—— Nudibranchiata	8
Pteropoda	1
Conchifera Lamellibranchiata	92
—— Brachiopoda	1
	223

Since that time 36 species have been added to the list, arranged as follows:—

Gasteropoda Prosobranchiata	14
—— Opisthobranchiata	1
—— Nudibranchiata	14
Pteropoda	0
Conchifera Lamellibranchiata	5
—— Brachiopoda	2
	36
Formerly found	223
Making in all	259 species.

The most interesting of the newly added species are *Cerithiopsis tubercularis* (2 specimens), *Mangelia levigata*, var. (1 specimen), *Buccinopsis Dalei* (1 specimen), *Trochus Groenlandicus* (1 specimen), *Fusus propinquus* (several specimens), *Odostomia pallida* (1 specimen), *Propilidium ancyloides*, *Am-*

phispbyra, n. s. (4 specimens), supposed to be the same species as that found by Mr. Dawson in shell-sand from Unst, and noticed by Mr. Jeffreys in his Report to the Meeting of the Association of last year, *Montacuta Dawsoni*, described by Mr. Jeffreys in the second volume of his 'British Conchology,' *Pecten striatus*, *Punopea plicata*, *Tellina balaustina* (a perfect specimen), *Crania anomala*, and *Argiope cistellula*.

Of the Crustacea a full examination has not yet been made; but what has been done has brought to light several additions of interest and importance. Of the Macroura only six species were obtained, viz., *Stenorhynchus phalangium* and *S. tenuirostris* (many specimens), *Inachus Dorsettenis* (a few specimens), *Hyas coarctatus*, *Ebalia Cranchii* (several specimens), and *Atelecyclus heterodon* (one small specimen). The total absence of any of the genus *Portunus*, several of which are somewhat common in the Moray Firth, and the extreme paucity of *Atelecyclus heterodon*, plentiful on the Banffshire coast, are worthy of notice. Of the Anomoura the Paguridæ alone have been fully examined, and they are as follows:—*Pagurus Bernhardus*, *P. Cuanensis*, *P. Ulidianus* (one specimen), *P. Hyndmanni* (several specimens), and another small specimen, not yet identified. Of the Sessile-eyed Crustacea the examination has not been completed; but the following interesting species have been obtained, viz., *Cheirocratus mantis* and *Unciola planipes*, two species recently described by the Rev. A. M. Norman in the 'N. H. Transactions of Northumberland and Durham'; two *Ampelisce*, not yet announced as British, but described by Mr. Norman as *A. levigata* and *A. tenuicornis*; *Mysis spinifera*, not yet recorded as British; and another well-marked species, in all probability new. One specimen of *Sipunculus Bernhardus* was got.

The Echinodermata yielded nothing remarkable, except one specimen of *Brissus lyrifer*, which, it may be remarked, has also been found off the Banffshire coast, and one of *Psolus squamosus*, rather common on the Banffshire coast. Besides these the following species were found:—*Ophiura texturata*, *O. albida*, *Ophiocoma bellis*, *O. Ballii*, *O. granulata*, *O. rosula*, *Uraster rubens*; *Solaster papposa*, *Liudia fragilissima* (1 specimen), *Echinus sphaera*, *Echinocyamus pusillus*, *Spatangus purpureus* (many specimens), *Amphidotus cordatus*, and *A. roseus* (a good many specimens). The absence of *Palmipes membranaceus* and of *Goniaster equestris*, both rather plentiful on the Banffshire coast, is worthy of notice.

In the examination of the Polyzoa and Hydrozoa little has been done. *Hornera borealis*, a species not found before south of Shetland, was observed; and two of the *Lepraliæ* may turn out to be new.

Of the Actinozoa four species only were met with, at a depth of fifty-seven fathoms, viz. *Tealia crassicornis*, *Stomphia Churchiæ* (5 specimens), *Hormathia Margaritæ*, and *Caryophyllia Smithii* (a broken specimen). Of *Hormathia Margaritæ* the disk and tentacles only came up; but these agreed in every respect with the description given in the 'Actinologia Britannica.' The *Hormathia* lived for several days, expanding the tentacles, and doing its best in the miserable circumstances to enjoy life (!). The smallness of the number of the Actinozoa, when compared with the number of species found on the Banffshire coast (about eighteen, including the littoral species), is somewhat remarkable. One reason for the difference, no doubt, is the nature of the sea-bottom, that of Banffshire being in many places rocky or, as it is locally called, "hard."

The few Sponges that were got were sent to Dr. Bowerbank. They consisted of *Polymastia spinula*, *Hymeraphia stellifera*, and a very young *Hymeniacidon*, which was too immature for satisfactory determination.

It may be added that a small Lumpsucker, which the Committee have been unable to identify either from Yarrell's or Couch's 'British Fishes,' was brought up.

To complete the dredging of the coast, the Committee would ask a renewal of the grant. They would also suggest that it would be most desirable that their researches should be extended along the coast of Banffshire, which has already yielded so many species new to Britain and to science. A supplementary Report will be laid before the next Meeting of the Association.

An Account of Meteorological and Physical Observations in Three Balloon Ascents made in the years 1864 and 1865 (in continuation of twenty-two made in the years 1862, 1863, and 1864), under the auspices of the Committee of the British Association for the Advancement of Science, by JAMES GLAISHER, F.R.S., at the request of the Committee, consisting of Colonel Sykes, the Astronomer Royal, Lord Wrottesley, Sir D. Brewster, Sir J. Herschel, Bart., Dr. Lloyd, Dr. Lee, Dr. Robinson, Mr. Gassiot, Mr. Glaisher, Prof. Tyndall, Dr. Fairbairn, and Dr. W. A. Miller.

THE Committee on Balloon Experiments was reappointed last year, chiefly for the following purposes:—

- 1st. To examine the electrical condition of the air, if possible.
- 2nd. To verify the law of the decrease of temperature as found from summer-day observations, already made, with day observations at other seasons of the year, but principally in the winter and adjacent months.
- 3rd. It was understood that, in addition, magnetical experiments, whenever possible, were to be made in preference to all others; observations by the spectroscope (particularly on the solar spectrum), on the currents of the atmosphere, on solar radiation at different heights, and hygrometrical observations, though secondary, were to be held very important subjects of investigation, and to be followed as far as possible, according to circumstances.
- 4th. To make arrangements for observations at night, and to make observations at night, if possible.

With respect to the first of these objects, no further progress has been made; the instrument which was prepared last year, was prepared for use with an open-burning flame; this is not admissible with gas in such close proximity; and since the last Meeting I have been in hopes that Mr. Fleeming Jenkin, with Mr. Varley and Prof. Thomson, would be able to arrange an apparatus that might with safety be used; but, owing to engagements in connexion with the Atlantic Telegraph Cable, these gentlemen have not yet succeeded.

With respect to the second and third objects of research, some progress has been made, though not to the extent contemplated at the beginning of the year.

With respect to the fourth object, having relation to night observations, none have actually been made, but some arrangements have been completed, of which I will say a few words.

To take observations in the air at night, it is imperatively necessary to have some power of illumination, so that the instruments can be read.

Very many suggestions have been made for the benefit of the occupants of the car; among them phosphorus and the use of glow-worms have been mentioned. The latter I feared would lose their luminosity at a low temperature. The best of all seemed, however, to be a well-made miners' Davy-lamp; and through the kindness of my friends T. Sopwith, Esq., F.R.S., and E. Potter, Esq., of Tynemouth, two have been most carefully made by Mr. H. Watson, of Newcastle, of copper; so that their presence near to magnets is innocuous.

These lamps, with their lights burning, have been placed in a volume of gas, completely surrounded by it, without any bad effect following the immersion; and what is more important, I have had one of these lamps burning during an ascent made on the 27th of February of this year, coming down alight—the only difference between with and without the light being that in the latter case I had a source of heat to warm my cold fingers, which I never had before.

I consider that at present all necessary arrangements have been made for night observations, so far as light is concerned; and I cannot but regard this as an advance, although I have not any results to present of observations made at night, and we therefore are still in utter ignorance, without a single observation of the processes in operation at night to guide us, at any distance from the earth. Such a series of observations, even though only to the height of half a mile, would be very valuable indeed.

§ 1. INSTRUMENTS AND APPARATUS.

The instruments used were for the most part the same in construction as those in the preceding year; in addition, however, to them, there was a very fine spectroscope by Mr. Browning, and a delicately mounted magnet lent by Capt. Evans, F.R.S.

§ 2. OBSERVING-ARRANGEMENTS.

The instruments were in all cases placed on suitable framework attached to the outside of the car, and were in this position easily read by myself standing at the end of the car.

Circumstances of the Ascents, and General Observations.

Up to the last Meeting of the Association there had been 22 ascents, of which 17 had been made in the months of June, July, August, and September, and 5 only in the other months of the year, viz. 1 in January, 1 in March, 2 in April, and 1 in October. Of those made in the summer months, one only had been made in the morning, and 16 had been made in the afternoon or evening, with a declining sun.

Efforts were therefore directed to day experiments between the months of October and April, it being considered that the day and high experiments in summer already collected had better be brought together and discussed before any more of such experiments were made, and that in future attention should be directed to those points of research needing further elucidation.

I therefore devoted all my leisure between the months of October and April to securing as many ascents as I could between these times, and regret to

say that I succeeded in three only. The first of these was on December 1st, the second on December 30th, 1864, and the third on February 27th of the present year. These three ascents were made from Woolwich Arsenal.

Although I have so few ascents to speak of, it must be borne in mind that winter is the most difficult season of the year to pursue balloon experiments; yet as mountains are not climbed at this time of the year, and so few experiments have hitherto been made by means of the balloon, we are in almost entire ignorance of everything connected with the higher regions of the atmosphere during this cold portion of our year, in respect to the progressive diminution of temperature with elevation, the diffusion of vapour in the atmosphere, the density of clouds, their extent, and the currents in the atmosphere.

It is therefore the most important season for experiments; and these will be exceeded in value only by night experiments.

Ascent from Woolwich Arsenal, December 1, 1864.—The balloon left the earth at 2^h 37^m p.m., the temperature of the air at the time being 48°; and this value remained almost unchanged till the height of 600 feet was passed (increasing slightly in fact at first), and then very gradually declined to 31½° at about one mile in height.

Ascent from Woolwich Arsenal, December 30, 1864.—The balloon left at 2^h 13^m p.m., with a temperature at the time of 42½°; it declined 2° in the first 500 feet; at 1000 feet high it was 37°, or showing a decrease of 5½°; at 2000 feet it was 33½°, showing a further decline of 3½° in this 1000 feet. At 2500 feet high we met with cloud; the temperature was 31°. At 3300 feet, just at the upper surface of the cloud, the temperature was 27°; on getting above the cloud the temperature rose, and when 400 feet above it had increased to 31½°.

Ascent from Woolwich Arsenal, on February 27, 1865.—We left the earth at 1^h 58^m p.m.; the temperature of the air was 52°, declined gradually to 35°, when cloud was reached, which proved to be 1000 feet in thickness; during the passage through it there was no change of temperature, but on passing above it the temperature increased with the elevation.

By comparing these results with those taken in the period of summer they differ very greatly, and plainly show that *the laws of temperature holding good at one season are different from those at other seasons of the year.*

The balloon's courses in these three ascents were very nearly the same after attaining a certain elevation. On the 1st of December, on reaching 1100 feet, the current of air changed from W. to S.W.; at 2000 feet a W.N.W. current was entered; at 5000 feet the air was moving W.N.W., and we approached the sea, compelling us to descend near Rochester at 4^h 25^m p.m.

In the second ascent the wind was nearly south on the earth when the inflation began; it changed to W. nearly, and pilot balloons at a moderate elevation moved N.W. On leaving, the balloon first moved E.N.E.; when 500 feet high we entered a W. current, and, as before, moved towards the sea. It was at first intended to descend near the river Thames; but on coming within 300 feet of the earth the wind changed and we went somewhat inland, and descended, at 3^h 20^m, near to Stamford Le Hope.

During the month of January, and the greater part of February, as far as could be determined from daily observation from the Royal Observatory, Greenwich, the general prevalence of the wind in the higher regions of the air was W. and S.W. On February 27th the direction of the wind on the earth

was N., and apparently steady in that direction while the balloon was being filled. On its completion the wind had changed to the S., and 4 or 5 hours' observations were looked forward to.

On reaching the height of 1500 feet, the balloon again fell in with the prevalent S.W. current, and at 3000 feet was in a nearly W. current, and again passed over the like course, directly towards the sea. It was therefore not deemed prudent to ascend very high. When above the lower clouds they were seen moving at right angles to the balloon's motion. Approaching the sea, it was necessary to descend; and on again reaching the height of 3000 feet the balloon fell in with the S.W. current, at 1500 feet with the S. current, and with this passed somewhat inland; on again reaching 3000 feet, we turned to move again directly towards the sea, and descended at South Hanningfield at 4^h 1^m.

After this I did not succeed in ascending, and since April I have mostly been taking steps towards securing some night ascents.

It is unfortunate, in one sense, that the wind on these occasions, notwithstanding its direction on the land, was so constantly at certain elevations moving with a W., W.S.W. or S.W. current, because on all occasions it so shortened the time of observation, and limited the elevation to such heights only that we were certain of being able to descend before reaching the sea.

Yet the fact is important, and very much so, as proving the constancy of the S.W. current during our winter months; for the evidence of such current is not merely confined to these three days only, but a continued watch was kept on the higher regions from the Royal Observatory, and whenever scud or cloud has been seen at the proper elevation, it has been found to be moving in that direction. The high temperature we experience in winter seems to be very much due to the prevalence of the warm current.

In these three ascents, Frederick John Evans, Esq., Staff Commander R.N., F.R.S., Superintendent of the Compass Department of Her Majesty's Navy, very kindly furnished me with a very delicate magnet, which he uses on board of iron ships and in the Compass Department.

This instrument vibrates in a little more than two seconds on the earth. In the ascent on December 1, I was able to take ten sets of vibrations; and notwithstanding the lower temperature of the higher regions, the time of vibration was lengthened.

In the ascent on December 30, the balloon was in a constant state of rotation, and I was unable to take any magnetic observations.

In the ascent on February 27, the same needle vibrated in 2.001 seconds on the earth, at the height of one mile vibrated in 2.277 seconds nearly. These results were confirmed by another magnet, somewhat less delicately mounted, its time of vibration being found to be longer at high elevations than on the earth. These results agree with those found at other times of the year.

The Lines in the Solar Spectrum.

At every opportunity I directed the spectroscope to the sun, and always saw a very fine spectrum, with very many lines, far greater in number than when viewed on the earth, and much better defined. The spectrum usually extended from A to far beyond H, the latter line being plainly made up of fine lines. I have never seen the spectrum of the sun, when viewed on the

earth, nearly so brilliant as it always is on rising above the lower atmosphere, although I have examined the solar spectrum many hundreds of times on the finest days. The spectrum, when viewed from above, is perfect with a much narrower opening of the slit than it is on the ground, and consequently lines can be resolved clearly which cannot be seen from the earth.

A very delicate blackened-bulb thermometer, placed with its bulb near to the carefully screened bulb for temperature of the air, in the first of these three ascents, generally read the same as that for the temperature of the air, occasionally read lower, and never during the ascent read more than 1° in excess. The same results were observed in the ascent on December 30th. In the ascent on February 27 it generally read the same; but at times, when the sun was shining the brightest, it read from 2° to 3° higher than its shaded neighbour.

No tinge of ozone was shown on any test-paper spread freely about on the rigging in any of these journeys.

§ 3. DESCRIPTION OF THE TABLE OF OBSERVATIONS.

All the meteorological observations taken during the ascents are contained in Table I.

Column 1 contains the times at which the observations were made. Column 2 contains observations of the siphon barometer corrected for temperature and index error. Column 3 contains the readings of the thermometer attached to the barometer. Column 4 contains the readings of an aneroid barometer. Column 5 contains the height above the level of the sea, as reduced from the barometric readings in column 2 on the days the siphon barometer was used, and from column 4 on other days, by the formula of Baily, checked at intervals by that of Laplace, which is as follows:—

$$Z = \log \left(\frac{h}{h'} \right) \times 60159 \left(1 + \frac{t+t'-64}{900} \right) \left(1 + 0.002837 \cos 2L \right) \left(1 + \frac{z+52251}{20886900} \right),$$

where Z is the height required, and h, h', t and t' the height of the barometer, corrected for temperature, and the temperature of the air at the lower and upper stations respectively, L the latitude. The temperature of the air for the position of the balloon has been derived from the readings in column 10, when such have been taken, otherwise from column 6. Columns 6 to 9 contain the observations with the dry- and wet-bulb thermometers free, and the deduced dew-point. Column 10 contains the readings of a gridiron thermometer. Columns 11 to 14 contain the observations with the dry- and wet-bulb thermometers aspirated, and the deduced dew-point. Columns 15 and 16 contain the direct dew-point observations with Daniell's and Regnault's hygrometers. When numbers are entered in columns 15 and 16 with "no dew" affixed to them, it is meant that the temperature of the hygrometer has been lowered to the degree stated, but that no dew has been deposited. Column 17 contains the readings of a very delicate blackened-bulb thermometer fully exposed to the sun's rays.

The Astronomer Royal had observations made every ten minutes at the Royal Observatory, Greenwich, on the days of ascent, by Mr. Nash of the Magnetical and Meteorological Department.

The height of Greenwich barometer-cistern above the mean sea-level is 159 feet.

TABLE I. A.—Meteorological Observations made in the Twenty-third

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Attached Therm.			Dry.	Wet.
	h m s 11 35 0 p.m.	in.	o	in.	feet.	o	o
(1)							
		30°192	61°0	30°15		46°2	43°5
(2)	1 15 0 "					46°8	43°2
(3)	2 30 0 "	30°063	50°0	30°10	ground.	48°0	44°2
(4)	2 37 0 "			29°95	206	48°2	44°1
	2 38 0 "			29°61	498	48°0	44°0
(5)	2 38 30 "			29°38	644	47°5	43°2
(6)	2 39 0 "	29°042	51°0	29°20	890	47°2	43°3
(7)	2 40 0 "			28°85	1,230	46°0	42°0
(8)	2 41 0 "	28°413	51°0	28°45	1,618	45°0	41°2
(9)	2 42 0 "			28°23	1,831	43°5	40°2
(10)	2 43 0 "			27°80	2,248	43°0	38°7
	2 44 0 "			27°40	2,636	41°0	36°0
	2 45 0 "			26°70	3,298	44°0	36°0
(11)	2 46 0 "	26°426	47°0	26°42	3,570	39°5	34°9
	2 48 0 "			26°19	3,804	38°5	33°0
	2 50 0 "			25°78	4,222	38°0	32°0
	2 51 0 "			25°68	4,324	38°0	32°0
(12)	2 54 0 "			25°30	4,630	36°0	29°1
(13)	2 55 0 "	25°110	47°0	25°19	4,742	35°0	28°5
(14)	2 57 0 "			24°90	5,038	33°0	26°1
	2 58 0 "			24°70	5,328	31°5	26°1
(15)	2 59 0 "	24°690	46°0	24°70	5,328	31°5	26°1
	3 5 0 "			25°50	4,496	31°2	26°5
	3 6 0 "						
(16)	3 6 30 "			25°67	4,319	31°2	26°5
	3 8 0 "			25°80	4,184	33°0	29°1
(17)	3 9 0 "			25°85	4,128	33°5	29°8
	3 10 0 "			25°80	4,170	34°5	30°0
	3 14 0 "			25°09	4,766	32°2	29°1
(18)	3 15 0 "	24°891	46°0	24°92	4,909	31°8	27°2
(19)	3 17 0 "			24°90	4,951	31°0	27°1
(20)	3 23 0 "			24°78	5,052	30°2	25°1
	3 24 0 "			24°72	5,122	29°8	25°0
(21)	3 26 0 "			24°70	5,197	30°2	25°1
	3 27 0 "			25°00	4,931	30°2	25°2
	3 32 0 "			25°50	4,489	31°5	28°1
(22)	3 33 0 "			25°45	4,541	32°0	28°1
(23)	3 34 0 "			25°20	4,805	32°0	28°1
	1.	2.	3.	4.	5.	6.	7.

NOTES AND

- (1) Sun shining; clear sky; wind N.N.W., light and variable.
 (2) Cloudy; a pilot balloon first moved W., then N.W.
 (3) Sky clear. (4) Wind very nearly W.
 (5) A gun fired; felt the shock. (6) Sun shining brightly.
 (7) Entered a S.W. current, moving towards the part of the river north of Erith. Very misty all round. (8) Sun shining brightly.
 (9) Report of proving guns at Woolwich; perceptible vibration, every rope and the instruments were shaken.
 (10) Opened the valve; nearly opposite Belvedere.
 (11) Sun warm. (12) Between Erith and Belvedere,

Balloon Ascent, from Woolwich Arsenal, December 1, 1864.

mometers (free).		Gridiron Thermo- meter.	Dry and Wet Therms. (aspirated).				Hygrometers.		Delicate Blackened- bulb Ther- mometer.
Difference.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.	
°	°	°	°	°	°	°	°	°	°
.....		46°5					40°2		56°0
2'7	40°4						40°0		56°0
3'6	39°1	46°8					40°0	40°0	56°0
3'8	40°0	48°0					40°0	40°0	56°0
4'1	39°6	48°2							56°0
4'0	39°6								56°0
4'3	38°5	48°0							56°0
3'9	38°9								47°0
4'0	37°4								47°0
3'8	36°8								44°5
3'3	36°3								44°5
4'3	37°9								44°5
5'0	29°7								44°5
8'0	29°7								44°5
4'6	28°6								40°0
5'5	25°6								40°0
6'0	23°8						20°0		40°0
6'0	23°8	38°5							39°0
6'9	18°7								39°0
6'5	15°5								35°5
6'9	12°5						[dew		35°5
5'4	12°2						17°0 no		35°5
5'4	12°2						[dew		35°5
4'7	15°6						15°0 no		33°0
.....		35°0							33°0
4'7	15°6								33°0
3'9	21°3								33°0
3'7	21°9								29°5
4'5	22°4						[dew		29°5
3'1	22°0						16°0 no		31°5
4'6	16°6						[dew		31°5
3'9	16°5						19°0 no		31°0
5'1	9°1								31°0
4'8	9°8								30°0
5'1	8°9								30°0
5'0	8°9								30°0
3'4	9°6								30°0
3'9	9°1								30°0
3'9	9°1								30°0

GENERAL REMARKS.

(13) Ozone = 0.

(14) Wind N.N.W.

(15) Nearly opposite Erith; hills and dales distinctly visible.

(16) Sun-spectrum very fine.

(17) Sand out.

(18) A little to the right, or nearly over Dartford.

(19) Moving towards Cobham Park.

(20) Cannot get any dew on either Daniell or Regnault.

(21) No ozone.

(22) South of Greenhithe; smoke near the earth moving S., but after reaching 1000 feet moving N.

(23) In a line with Northfleet; we shall pass over Cobham Park.

TABLE I. A.—Meteorological Observations made in the Twenty-third

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Attached Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	3 40 o p.m.			24.78	5,245	30.0	27.2
	3 41 o "			24.63	5,403	29.5	26.5
	3 42 o "			24.60	5,431	29.1	26.1
	3 43 o "			24.95	5,063	30.0	27.2
	3 44 o "			25.52	4,464	31.2	28.1
	3 45 o "			26.45	3,487	32.8	29.5
(2)	3 46 o "			26.47	3,470	33.0	29.5
	3 46 30 "			26.45	3,491	33.0	29.8
	3 47 o "			26.20	3,759	33.0	29.7
	3 48 o "			26.00	3,973	33.0	27.8
(3)	3 49 o "			25.82	4,170	33.0	28.0
(4)	3 50 o "			26.00	3,968	33.0	28.0
	3 51 o "			26.16	3,789	32.7	28.2
(5)	3 52 o "			26.20	3,744	32.4	28.5
(6)	3 53 o "			26.20	3,744	32.1	28.7
	3 54 o "			26.65	3,240	32.5	30.0
	3 54 30 "			26.75	3,124	32.5	30.5
	3 55 o "			26.80	3,082	32.8	30.8
	3 55 30 "			27.00	2,914	33.0	31.1
(7)	3 56 o "						
	3 57 o "			27.30	2,662	34.0	32.0
(8)	3 58 o "			27.45	2,536	34.5	33.0
(9)	3 59 o "			27.50	2,497	35.2	33.5
	4 0 o "			27.30	2,691	35.5	33.6
(10)	4 1 o "			27.30	2,691	35.6	33.6
(11)	4 1 30 "			27.20	2,788	35.7	33.6
(12)	4 2 o "			27.14	2,847	35.5	33.1
(13)	4 3 o "			27.25	2,744	35.0	33.0
	4 4 o "			27.40	2,603	35.5	33.3
	4 5 o "			28.00	2,039	36.2	34.8
(14)	4 6 o "			28.25	1,804	37.1	35.0
(15)	4 7 o "			28.30	1,759	37.3	35.5
(16)	4 8 o "			28.42	1,644	38.3	36.5
	4 8 30 "			28.50	1,569	38.3	37.0
(17)	4 9 o "			28.52	1,550	38.7	37.5
	4 10 o "			28.60	1,475	39.0	38.0
(18)	4 13 o "			28.70	1,381	42.0	40.3
(19)	4 14 o "			28.80	1,280	42.1	40.2
(20)	4 15 o "			28.60	1,394	42.0	39.5
	4 15 30 "			28.50	1,451	41.5	39.2
(21)	4 17 o "			28.35	1,532	41.2	38.7
	4 18 o "			28.40	1,496	40.5	39.0
	4 19 o "			28.50	1,424	41.5	39.5
	4 20 o "			28.70	1,280	42.0	39.7
	1.	2.	3.	4.	5.	6.	7.

(1) No dew on either Daniell's or Regnault's Hygrometers.

(2) A chill to sense; sand thrown out.

(3) Heard voices.

(4) The setting sun illuminated the topmost part of a dark stratus cloud, with a very deep orange-colour; not a cloud in the sky above altitude 15°. Put magnets away.

(5) A sudden chill again.

(6) Sand thrown out.

(7) Wind W.N.W.; smoke below moving S.

(8) Heard a clock strike 4^h plainly.

(9) Sand thrown out.

(10) Saw a railway-train.

(11) Heard people calling out.

Balloon Ascent, from Woolwich Arsenal, December 1, 1864 (*continued*).

mometers (free).		Gridiron Thermo- meter.	Dry and Wet Therms. (aspirated).				Hygrometers.		Delicate Blackened- bulb Ther- mometer.
Difference.	Dew-point.		Dry.	Wet.	Diff.	Dew- point.	Daniell's. Dew-point.	Regnault's. Dew-point.	
0	0	0	0	0	0	0	0	0	0
2.8	18.4								
3.0	16.5								
3.0	15.3								
2.8	18.4								
3.1	19.5								
3.3	22.9								
3.5	22.5						21.5		
3.2	23.1								
3.3	23.1							[dew	
5.2	17.4							15.0 no	33.0
5.0	15.0								
5.0	15.0								
4.5	19.2						[dew		
3.9	20.0						20.0 no		
3.4	21.3								
2.5	24.7						25.0		
2.0	25.0								
2.0	29.2								
1.9	27.3								
2.0	28.5						28.0		
1.5	30.5								
1.7	30.8								
1.9	30.7						30.0		
2.0	30.5								
2.1	30.3								
2.4	29.4								
2.0	29.8								
2.2	30.0								
1.4	32.7								
2.1	32.3								
1.6	33.0								
1.8	34.1								
1.3	35.2								
1.2	35.8								
1.0	36.7								
1.7	36.8								
1.9	37.9								
2.5	36.4								
2.3	36.3								
2.5	35.5								
1.5	37.1								
2.0	37.0								
2.3	36.4								
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.

(12) A great deal of moisture on the balloon.

(13) Nearly south of Gravesend.

(14) Heard many voices.

(15) Can hear cries of "come down;" wooded country.

(16) Cobham Park.

(17) Moist to sense.

(18) Moisture almost dropping from the balloon.

(19) Approaching the Medway.

(20) Ascending to a higher current to cross the river.

(21) We can see Rochester Bridge and Castle.

TABLE I. A.—Meteorological Observations made in the Twenty-third

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Attached Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	4 21 0 p.m.			28.80	1,208	41.2	39.7
	4 21 30 "			28.82	1,194	41.3	39.7
	4 22 0 "			28.90	1,137	41.0	40.2
	4 23 0 "			29.12	979	41.1	40.2
(1)	4 35 0 "				} ground {	45.2	43.0
	4 33 0 "			29.82			

TABLE I. B.—Meteorological Observations made in the Twenty-fourth

(2)	2 12 0 p.m.			29.86	} ground {	42.5	39.0
	2 12 45 "					42.1	38.5
	2 13 0 "			29.80	80	41.0	37.2
(3)	2 14 0 "			29.51	355	40.0	36.2
	2 15 0 "			29.25	602	39.0	36.0
	2 15 30 "			29.05	782	38.2	35.1
(4)	2 16 0 "			28.95	877	37.2	34.8
	2 16 30 "			28.80	1,020	36.2	34.2
	2 16 45 "			28.50	1,321		
	2 17 0 "						
	2 18 0 "						
	2 18 30 "			27.80	1,995	34.1	32.9
	2 19 0 "			27.60	2,220	33.0	32.0
(5)	2 19 30 "			27.50	2,310	32.5	32.0
(6)	2 19 45 "			27.45	2,355	32.7	31.8
	2 20 0 "			27.40	2,410	32.5	31.9
(7)	2 21 0 "			27.10	2,634	32.2	31.5
	2 22 0 "			27.05	2,699	31.9	30.5
(8)	2 23 0 "			27.05	2,699	31.9	30.8
(9)	2 24 0 "			27.11	2,641	31.9	30.5
(10)	2 25 0 "			27.40	2,350	31.9	31.0
(11)	2 26 0 "			27.45	2,301	31.9	31.2
	2 27 0 "			27.68	2,077	31.9	31.6
(12)	2 27 15 "			27.75	2,019	32.3	32.0
	2 27 30 "						
(13)	2 28 0 "			27.55	2,215	32.2	32.2
	2 28 15 "			27.40	2,362	31.5	31.2
(14)	2 28 30 "			27.21	2,552	31.3	30.6
(15)	2 28 45 "						
(16)	2 29 0 "			26.92	2,822	29.5	29.0
	2 29 30 "			26.71	3,018	28.8	28.3
(17)	2 29 45 "						
(18)	2 30 0 "			26.48	3,228	27.5	27.2

1.

2.

3.

4.

5.

6.

7.

(1) On the ground at Delce Farm, near Rochester.

(2) Left the earth.

(3) Mist all round.

(4) Cold.

(5) Dropped the grapnel.

(6) Approaching cloud.

(7) In cloud.

(8) Just out of cloud; and over the wall of the river.

(9) At least 150 vessels in sight.

(10) Out of cloud.

Balloon Ascent, from Woolwich Arsenal, December 1, 1864 (*continued*).

mometers (free).		Gridiron Thermo- meter.	Dry and Wet Therms. (aspirated).				Hygrometers.		Delicate Blackened- bulb Ther- mometer.
Difference.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.	
0	0	0	0	0	0	0	0	0	0
1'5	37'4								
1'6	37'2								
0'8	39'2								
0'9	39'1								
2'2	40'5								

Balloon Ascent, from Woolwich Arsenal, December 30, 1864.

3'5	34'8								
3'6	34'1								
3'8	32'4								
2'8	31'2								
3'0	32'0								
3'1	30'9								
2'4	31'5								
2'0	31'2								
.....							30'5		
.....								30'0	
1'2	30'8								
1'0	30'0								
0'5	31'0								
0'9	30'0								
0'6	30'7								
0'7	30'0							28'0	
1'4	27'1								
1'1	28'3								
1'4	27'2								
0'9	28'9								
0'7	29'6								
0'3	30'9	30'5							
0'3	30'4								
0'0	32'2								
0'3	30'4								
0'7	28'9								
0'5	27'3								
0'5	26'4								
.....								27'0	
0'3	26'0								
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.

(11) Our course is taking each bight of the river.

(12) Sand out.

(13) Cold to sense; approaching cloud.

(14) Edge of cloud.

(15) Entered cloud; lost sight of everything.

(16) Very cold.

(17) Much lighter; very cold.

(18) Cloud dense and cold; fog dazzlingly bright.

TABLE I. B.—Meteorological Observations made in the Twenty-fourth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Attached Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	2 31 0 p.m.			26.28	3,424	27.2	26.5
	2 32 0 "			26.12	3,580	30.0	26.0
(2)	2 32 15 "			26.12	3,580	29.5	26.2
	2 33 0 "			26.00	3,735	31.5	26.0
(3)	2 34 0 "						
	2 34 15 "			26.15	3,589	29.5	26.2
	2 34 30 "			26.15	3,589	29.0	27.2
(4)	2 34 40 "						
	2 34 45 "			26.25	3,492	28.2	27.1
	2 35 0 "			26.50	3,249	28.2	27.0
(5)	2 35 30 "			27.20	2,570	28.2	28.0
(6)	2 36 0 "			27.65	2,133	30.2	29.7
	2 37 0 "			28.90	932	33.0	32.0
(7)	2 38 0 "			28.95	837	34.0	32.5
	2 39 0 "			29.05	797	34.5	32.9
(8)	2 40 0 "			29.18	689	35.2	33.5
	2 41 0 "			29.05	1,009	35.9	33.8
(9)	2 41 30 "			28.90	1,369	36.0	33.9
	2 42 0 "			28.72	1,669	35.5	33.8
	2 43 0 "			28.60	1,929	35.5	33.5
	2 43 30 "			28.52	2,129	35.5	33.2
	2 44 0 "			28.48	2,219	35.5	33.2
	2 45 0 "			28.32	2,589	34.9	32.8
	2 45 30 "			28.30	2,699	34.5	33.0
	2 46 0 "			28.26	2,829	34.2	32.5
	2 47 0 "			28.25	2,860	34.0	33.0
	2 47 30 "			28.24	2,946	34.0	33.0
	2 48 0 "			28.40	2,796	34.0	33.0
	2 48 30 "			28.40	2,796	34.0	33.0
	2 49 0 "			28.40	2,796	34.0	33.0
	2 49 30 "			28.45	2,666	34.5	33.3
	2 49 45 "			28.50	2,536	35.0	33.2
	2 50 0 "			28.60	2,276	35.3	33.2
	2 50 30 "			28.68	2,070	35.6	33.5
	2 51 0 "			28.85	1,621	35.6	33.5
	2 51 30 "			28.92	1,462	35.6	33.8
	2 51 45 "			29.00	1,256	35.8	33.8
	2 52 0 "			29.10	1,096	36.0	34.0
	2 53 0 "			29.35	556	36.2	34.0
	2 53 30 "			29.38	511	36.2	34.5
	2 54 0 "			29.39	495	36.2	34.5
	2 54 30 "			29.32	556	36.2	34.5
	2 55 0 "			29.31	565	36.1	34.5
	2 57 0 "			29.60	299	38.2	36.7
	2 57 30 "			29.31	570	38.2	36.7
(10)	2 58 30 "			29.20	670	38.2	35.5
	2 59 0 "			28.95	900	37.2	36.0
	3 0 0 "			28.78	1,056	37.2	36.0
	1	2.	3.	4.	5.	6.	7.

(1) Sun shining dazzlingly. A beautiful sky of Prussian blue; not a cloud above us; beautiful sea of cloud below of varied surface, bright and shining.

(2) Sun brighter still.

(3) Sun observed in mist.

(4) In a very dense cloud.

(5) Out of cloud.

Balloon Ascent, from Woolwich Arsenal, December 30, 1864 (*continued*).

mometers (free).		Gridiron Thermo- meter.	Dry and Wet Therms. (aspirated)				Hygrometers.		Delicate Blackened- bulb Ther- mometer.
Difference.	Dew-point.		Dry.	Wet.	Diff.	Dew- point.	Daniell's. Dew-point.	Regnault's. Dew-point.	
0	0	0	0	0	0	0	0	0	0
0.7	23.4								
4.0	13.4								
3.3	15.0								
5.5	12.2						15.0	14.0	
3.3	15.1								
1.8	20.7								29.0
1.1	22.7								
1.2	22.3	28.5							
0.2	27.3								
0.5	28.3								
1.0	30.0								
1.5	29.0								
1.6	30.2								34.5
1.7	30.8								
2.1	30.6	36.0							
2.1	30.8								
1.7	31.2								35.5
2.0	31.1								35.5
2.3	29.6								
2.3	29.6	35.3					30.0		
2.1	29.5								
1.5	30.5								
1.7	29.6								
1.0	31.2								
1.0	31.2								
1.0	31.2								
1.0	31.2								
1.2	31.2								
1.8	30.3								
2.1	29.9								
2.1	30.3								
2.1	30.3	35.5							
1.8	31.1								
2.0	30.8							30.5	
2.0	31.0								
2.2	30.8								
1.7	32.0								
1.7	32.0								
1.7	32.0								
1.6	32.1							32.5	
1.5	34.7								
1.5	34.7								
2.7	34.9								
1.2	34.4								
1.2	34.4								

8.

9.

10.

11.

12.

13.

14.

15.

16.

17.

(6) Falling quickly; revolving in 2 minutes.

(7) We are about a mile north of Purfleet.

(8) Moving W.S.W.

(9) Moving towards Sea Reach.

(10) Sand thrown out.

TABLE I. B.—Meteorological Observations made in the Twenty-fourth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Attached Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	3 1 o p.m.			28·62	1,203	37·2	35·7
	3 2 o "			28·55	1,266	37·2	35·6
	3 2 30 "			28·60	1,216	37·5	36·0
(1)	3 3 o "			28·70	1,116	37·8	36·0
	3 3 45 "			29·05	766	37·8	36·2
	3 4 o "			29·42	396	38·2	36·4
	3 5 o "			29·50	316	38·2	36·4
(2)	3 6 o "			29·63	186	38·2	36·4
(3)	3 10 o "				} ground {	38·2	36·5
	3 15 o "			29·82			

TABLE I. C.—Meteorological Observations made in the Twenty-fifth

	1 25 o p.m.			30·27	} ground {	47·7	42·4
(4)	1 34 o "					47·5	42·0
(5)	1 52 o "			30·20		52·1	45·2
(6)	1 58 o "						
	1 58 10 "			30·13	60	51·8	45·2
	1 58 20 "			30·00	176	51·4	44·8
	1 58 30 "			29·92	244	51·0	44·1
	1 59 o "			29·65	474	49·5	42·1
(7)	2 o o "			29·30	767	47·2	40·9
(8)	2 1 o "						
(9)	2 1 30 "			28·98	1,085	46·2	40·1
	2 2 o "			28·52	1,543	45·2	40·1
(10)	2 2 30 "			28·21	1,851	43·7	38·9
	2 2 45 "			27·78	2,279	41·2	37·1
	2 3 o "						
(11)	2 3 30 "			26·98	3,074		
(12)	2 4 o "			26·72	3,333	35·5	33·0
(13)	2 5 o "			26·42	3,632	34·8	32·0
(14)	2 5 30 "			26·20	3,851	34·8	32·0
	2 6 o "			26·05	3,990	35·0	31·6
(15)	2 6 30 "			26·00	4,040	34·8	30·9
(16)	2 7 30 "			25·62	4,418	34·0	29·2
(17)	2 8 30 "			25·39	4,647	34·0	28·3
	2 9 o "			25·34	4,697	34·5	28·5
(18)	2 9 30 "			25·30	4,737	35·2	29·0
(19)	2 11 o "			25·30	4,737	38·2	31·1
	2 11 30 "			25·25	4,795	38·2	30·6

1.

2.

3.

4.

5.

6.

7.

(1) Moving direct for Sea Reach; we must come down if we do not change our direction.

(2) Packed up all the instruments, cleared the tops of some trees, and came down within a mile of the river, near the Railway Station at Stanford le Hope.

(3) On the ground.

(4) A pilot balloon went nearly due N.

(5) Wind S.

(6) Left the earth.

(7) Over the river.

(8) Bells sound very clearly.

(9) Wind S.W.; sun obscured by cloud.

(10) Moving towards Barking Creek; moving N.E.

(11) In cloud; cold.

(12) In a white cloud.

(13) Faint gleams of light.

Balloon Ascent, from Woolwich Arsenal, December 30, 1864 (*continued*).

mometers (free).		Gridiron Thermo- meter.	Dry and Wet Therms. (aspirated).				Hygrometers.		Delicate Blackened- bulb Ther- mometer.
Difference.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.	
0	0	0	0	0	0	0	0	0	0
1.5	36.2								
1.6	33.4								
1.5	34.0								
1.8	34.2								
1.6	34.0								
1.8	33.9								
1.8	33.9								
1.8	33.9								
1.7	34.2								

Balloon Ascent, from Woolwich Arsenal, February 27, 1865.

5.3	36.5								
5.5	35.9								
6.9	38.0							34.2	
.....									52.0
6.6	38.5								
6.6	38.1								52.0
6.9	36.9								
7.4	34.1								51.5
6.3	33.9								
6.1	33.2								
5.1	34.2								
4.8	33.1								
4.1	32.0								
.....								29.0	
2.5	29.1								
2.8	27.5								
2.8	27.5								
3.4	27.2								
3.9	24.7								35.0
4.8	20.9						18.5		
5.7	18.2								
6.0	17.1								
6.2	19.1								
7.1	21.6							19.0	
7.6	20.3								
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.

(14) We are in cloud, and over water; the clouds below are moving much more quickly than we; wind more westerly.

(15) Sun shining faintly; clouds at least three or four miles above us, moving W.; we are in a N.W. current.

(16) Clouds below appear to be moving N.; we are moving towards the E.

(17) The clouds below are moving at right angles to us.

(18) Over Barking level; Tilbury line to our left or N.; clouds have a very fine purple tinge over a very beautiful even surface; N. gloomy and dark; great contrast.

(19) Sensibly warmer.

TABLE I. c.—Meteorological Observations made in the Twenty-fifth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Attached Therm.			Dry.	Wet.
	h m ■ p.m.	in.	°	in.	feet.	°	°
(1)	2 12 0			25°19	4,855	38°7	30°6
	2 12 30			25°17	4,875	38°7	29°7
	2 13 0			25°17	4,875	39°2	29°4
	2 17 0			25°08	4,965	39°2	29°2
	2 22 30					38°2	29°0
(2)	2 23 0			25°30	4,828	38°2	29°0
(3)	2 24 0			25°30	4,828	38°2	29°0
	2 25 0			25°30	4,828	38°2	29°0
(4)	2 27 0			25°30	4,828	38°2	27°5
	2 27 30			25°25	4,840	38°2	27°5
	2 28 0			25°22	4,847	38°1	27°2
	2 29 0			25°20	4,865	38°2	27°5
(5)	2 30 0			25°20	4,865	38°2	27°5
	2 34 0			25°60	4,408	39°2	29°5
	2 34 20			25°60	4,408	39°4	30°0
(6)	2 36 0			25°50	4,517	39°2	30°0
(7)	2 37 0						
	2 38 0			25°42	4,604	39°2	30°0
	2 40 0			25°30	4,734	41°2	31°5
	2 41 0			25°30	4,734	41°7	31°3
(8)						42°0	31°0
(9)	2 42 0			25°50	4,538	42°0	31°0
	2 42 30			25°70	4,332	43°2	32°5
	2 43 0			25°90	4,136	43°3	33°0
(10)	2 44 0			26°60	3,450	42°5	35°5
	2 45 0			26°78	3,274	42°0	36°0
	2 45 30			27°10	2,960	41°7	36°0
	2 46 0			27°35	2,715	40°7	35°5
(11)	2 46 20			27°40	2,676	40°5	36°0
	2 46 30			27°55	2,529	41°0	36°5
	2 47 0			27°70	2,382	41°0	37°5
	2 48 0			27°72	2,360	41°0	38°0
(12)	2 48 30			27°72	2,360	41°2	38°0
	2 49 0			27°75	2,330	41°8	38°0
	2 50 0			27°80	2,281	43°0	39°5
	2 51 0			28°05	2,035	43°2	39°0
	2 54 0			29°31	796	44°2	40°2
	2 55 0			29°80	322	46°2	41°0
	2 56 0			29°65	460	46°2	41°0
	2 56 30			29°45	644	46°0	41°2
	2 57 30			29°14	927	44°5	40°0
	2 58 0			29°11	957	43°5	39°5
	2 59 0			29°00	1,057	43°5	39°0
	2 59 30			28°90	1,148	43°5	38°5
(12)	3 0 0			28°92	1,130	43°0	38°5
	3 1 0			28°98	1,075	43°0	38°5
	3 1 30			28°99	1,066	43°5	38°5
	3 2 0			29°00	1,057	43°5	39°0
	3 3 0			29°07	990	43°5	39°5
	1.	2.	3.	4.	5.	6.	7.

(1) Over Dagenham Marsh.

(2) Lowered grapnel.

(3) Entered a more southerly current; about S.W.

(4) Clouds very high.

(5) Must come down.

(6) Sun again bright.

Balloon Ascent, from Woolwich Arsenal, February 27, 1865 (*continued*).

mometers (free).		Gridiron Thermo- meter.	Dry and Wet Therms. (aspirated).				Hygrometers.		Delicate Blackened- bulb Ther- mometer.
Difference.	Dew-point.		Dry.	Wet.	Diff.	Dew- point.	Daniell's. Dew-point.	Regnault's. Dew-point.	
8°1	19°4	o	o	o	o	o	o	o	o
9°0	17°7								
9°8	16°5								
10°0	16°1						15°0		
9°2	16°6								
9°2	16°6								
9°2	16°6								
9°2	16°6								
10°7	13°0							15°0±	
10°7	13°0								
10°9	12°4								38°3
10°7	13°0								
10°7	13°0								
9°7	16°7						17°0		
9°4	17°7							16°0	
9°2	17°9								
9°2	17°9								
9°7	19°3								45°0
10°4	18°5								
11°0	17°5								43°5
11°0	17°5								43°5
10°7	19°7								
10°3	20°7								
7°0	27°0								
6°0	28°6								42°5
5°7	28°9								
5°2	29°0								
4°5	30°2								
4°5	30°8								
3°5	33°1							33°0	
3°0	34°2								
3°2	34°0								
3°8	33°3						34°0		41°0
3°5	35°3								
4°2	34°0								
4°0	35°5								
5°2	35°1								
5°2	35°1								
4°8	35°7								46°0
4°5	34°7								
4°0	34°7						35°0		
4°5	33°6								
5°0	32°6								
4°5	33°1								
4°5	33°1								
5°0	33°1								
4°5	35°3								
4°0	34°7								

8. 9. 10. 11. 12. 13. 14. 15. 16. 17.

(7) Moving towards Long Reach.

(8) Sun hot.

(9) Opened valve.

(10) On level with lower clouds.

(11) Below cloud.

(12) Upper clouds moving as before; no sun.

1865.

TABLE I. c.—Meteorological Observations made in the Twenty-fifth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Attached Therm.			Dry.	Wet.
	h m s p.m.	in.	°	in.	feet.	°	°
(1)	3 4 0			29'11	953	43'5	39'0
	3 5 0			29'15	926	43'5	39'3
	3 5 30			29'50	605	43'5	39'0
	3 6 0			29'50	605	44'0	39'3
	3 7 0			29'61	504	44'5	40'0
	3 8 0			29'63	486	45'0	40'2
	3 9 0			29'68	441	45'3	40'3
	3 10 0			29'75	377	45'9	40'5
	3 11 0			29'80	322	45'5	40'4
	3 12 0			29'80	322	46'0	41'0
	3 12 30			29'65	459	46'0	41'0
	3 13 0			29'32	761	45'2	40'0
	3 14 0			29'30	779	45'2	40'0
	3 15 0						
	3 15 30			29'15	916	45'0	40'2
	3 16 0			29'00	1,053	44'2	39'8
	3 17 0			28'90	1,148	43'2	39'0
	3 17 30			28'90	1,148	43'2	39'0
	3 18 0			28'90	1,148	43'2	38'7
	3 19 0			29'08	978	43'2	38'5
	3 20 0			29'10	959	43'2	38'5
	3 21 0			29'30	770	43'2	38'0
	3 22 0			29'30	770	43'2	38'0
	3 23 0			29'30	770	43'2	38'1
	3 24 0			29'33	742	43'1	38'6
	3 25 0			29'50	582	43'3	39'0
	3 26 0			29'38	698	43'5	39'0
	3 27 0			29'20	872	43'5	39'2
(2)	3 28 0			29'30	969	43'3	39'0
	3 29 0			28'72	1,375	42'5	37'5
	3 30 0			28'55	1,463	42'0	37'3
	3 30 30			28'25	1,689	40'6	36'5
(3)	3 31 0			28'00	1,944	39'6	36'0
	3 32 0			27'90	2,046	38'9	35'5
	3 32 30			27'80	2,148	38'0	35'0
	3 33 0			27'72	2,230	37'9	35'0
(4)	3 34 0						
	3 35 0			27'68	2,271	37'2	35'0
(5)	3 37 0			27'50	2,455	37'2	34'5
	3 38 0						
(6)	3 38 30			27'30	2,659	36'5	33'9
(7)	3 39 0			27'00	2,965	36'0	33'5
(8)	3 40 0			26'82	3,149	35'2	33'0
(9)	3 41 0			26'82	3,149	35'2	33'0
	3 42 0			26'78	3,190	34'2	32'1
(9)	3 43 0			26'78	3,190	34'2	32'2
	3 43 +						
(9)	3 44 0			26'61	3,360	34'2	32'0
	3 44 0						

1.

2.

3.

4.

5.

6.

7.

- (1) Neck of the balloon tied up.
 (2) Twelve miles from Chelmsford.
 (3) Changed direction; moving W., I think.
 (4) Water looks like polished steel.

Balloon Ascent, from Woolwich Arsenal, February 27, 1865 (*continued*).

mometers (free).		Gridiron Thermo- meter.	Dry and Wet Therms. (aspirated).				Hygrometers.		Delicate Blackened- bulb Ther- mometer.
Difference.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.	
0	0	0	0	0	0	0	0	0	0
4.5	35.3								
4.2	34.3								
4.5	33.6								
4.7	33.8						34.0		
4.5	34.7								
4.8	34.6								
5.0	34.6								
5.4	34.4							32.0	
5.1	34.6								
5.0	35.3								
5.0	35.3								
5.2	34.0						34.0		
5.2	34.0							33.5	
4.8	34.6								
4.4	34.6								
4.2	34.0								
4.2	34.0								
4.5	33.3							33.0	
4.7	32.9								
4.7	32.9								
5.2	31.8								
5.2	31.8								
5.1	32.0								
4.5	33.2						34.0±		
4.3	33.9								
4.5	33.6								
4.3	34.0								
4.3	33.9								
5.0	31.4								
4.7	31.6								
4.1	31.2								
3.6								30.0	
3.4	31.3								
3.0	30.9								
2.9	31.0								
2.2	31.9						30.5		
2.7	30.7								
2.6	30.1								
2.5	29.7								
2.2	29.5								
2.2	29.5								
2.1	28.4								
2.0	28.7								
2.2	28.3								

8. 9. 10. 11. 12. 13. 14. 15. 16. 17

(5) Country brightened up by the sun. In haze.

(6) In thicker haze; only one bag of ballast.

(7) In cloud.

(8) In cloud.

(9) Mist.

TABLE I. c.—Meteorological Observations made in the Twenty-fifth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Attached Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	3 44 30 p.m.						
(2)	3 45 0 "			26.45	3,521	33.0	32.0
(3)	3 45 30 "			26.32	3,652		
	3 45 40 "			26.20	3,772	33.0	32.0
(4)	3 46 0 "			26.52	3,415	32.5	32.0
	3 47 0 "			26.72	3,218	32.5	31.7
	3 48 0 "			26.90	3,042	32.5	32.0
(5)	3 49 0 "			27.30	2,650	32.5	32.0
	3 50 0 "			27.32	2,637	33.1	32.7
	3 51 0 "			27.71	2,252	34.2	33.1
	3 52 0 "			28.20	1,793	35.5	33.0
	3 54 0 "			29.00	1,023	42.0	38.0
	3 55 0 "			29.30	731	42.5	38.7
	3 56 0 "			29.40	634	43.0	39.2
	3 56 30 "			29.47	561	43.8	39.5
	3 57 0 "			29.56	472	43.7	39.8
	3 57 30 "			29.70	448	44.0	40.2
	3 58 0 "			29.79	331	44.2	40.6
	3 59 0 "			29.80	322	44.4	40.8
(6)	3 59 30 "			29.85	70	44.5	40.9
	4 0 0 "			29.89	ground.	44.5	41.2

1.

2.

3.

4.

5.

6.

7.

(1) In cloud ; cold.

(2) In fog.

(3) Opened valve ; one bag of ballast only.

Balloon Ascent, from Woolwich Arsenal, February 27, 1865 (*continued*).

mometers (free).		Gridiron Thermo- meter.	Dry and Wet Therms. (aspirated).				Hygrometers.		Delicate Blackened- bulb Ther- mometer.
Difference.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.	
0	0	0	0	0	0	0	0	0	0
1'0	30'0						30'5		
1'0	30'0								
0'5	31'0						30'7		
0'8	30'0								
0'5	31'0							30'5	
0'5	31'0								
0'4	31'9								
1'1	31'2								
2'5	29'2								
4'0	33'1								
3'8	34'0								
3'8	34'6								
4'3	34'4								
3'9	35'1								
3'8	35'7								
3'6	36'4								
3'6	36'6								
3'6	36'7								
3'3	37'3								
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.

(4) In cloud.

(6) Just over some trees.

(5) Out of cloud.

§ 4. ADOPTED TEMPERATURES OF THE AIR, THE WET-BULB, AND THE DEW-POINT IN THREE BALLOON ASCENTS.

From all the observations of the temperature of the air, evaporation, and dew-point in Table I., a determination was made of these elements, with the corresponding reading or mean of readings of the barometer and heights, and then the next Table was formed.

TABLE II. A.—Showing the adopted Reading of the Barometer, calculated Height above the Sea, Temperature of the Air, Temperature of the Wet-bulb Thermometer, and Temperature of the Dew-point, in the

TWENTY-THIRD ASCENT.—December 1, 1864.

Time of observation. A.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	°	h m s	in.	feet.	°	°	°
11 35 0		on the ground	46.5			3 33 0	25.45	4541	32.0	28.1	9.1
	30.15		46.2	43.8		34 0 25.20	4805	32.0	28.1	9.1	
P.M.	30.19			43.2		40 0 24.78	5245	30.0	27.2	18.4	
1 15 0			46.8	43.2		41 0 24.63	5403	29.5	26.5	16.5	
2 30 0	30.10		48.0	44.2	40.0	42 0 24.60	5431	29.1	26.1	15.3	
37 0	29.95	206	48.2	44.1	39.6	43 0 24.95	5063	30.0	27.2	18.4	
38 0	29.61	515	48.0	44.0	39.6	44 0 25.52	4464	31.2	28.1	19.8	
38 30	29.38	584	47.5	43.2	38.5	45 0 26.45	3487	32.8	29.5	22.9	
39 0	29.20	890	47.2	43.3	38.9	46 0 26.47	3470	33.0	29.5	22.5	
40 0	28.85	1230	46.0	42.0	37.4	46 30 26.45	3491	33.0	29.8	23.1	
41 0	28.45	1618	45.0	41.2	36.8	47 0 26.20	3759	33.0	29.7	23.1	
42 0	28.23	1831	43.5	40.2	36.3	48 0 26.00	3973	33.0	27.8	17.4	
43 0	27.80	2248	43.0	38.7	37.9	49 0 25.82	4170	33.0	28.0	15.0	
44 0	27.40	2636	41.0	36.0	29.7	50 0 26.00	3968	33.0	28.0	15.0	
45 0	26.70	3298	40.0	36.0	29.7	51 0 26.16	3789	32.7	28.2	19.2	
46 0	26.42	3570	39.5	34.9	28.6	52 0 26.20	3744	32.4	28.5	20.0	
48 0	26.19	3804	38.5	33.0	25.6	53 0 26.20	3744	32.1	28.7	21.3	
50 0	25.78	4222	38.0	32.0	23.8			3759	32.4		
51 0	25.68	4324	38.0	32.0	23.8	54 0 26.65	3240	32.5	30.0	24.7	
54 0	25.30	4630	36.0	29.1	18.7	54 30 26.75	3124	32.5	30.5	25.0	
55 0	25.19	4742	35.0	28.5	15.5	55 0 26.80	3082	32.8	30.8	29.2	
57 0	24.90	5038	33.0	26.1	12.5	55 30 27.00	2914	33.0	31.1	27.3	
58 0	24.70	5328	31.5	26.1	12.2	57 0 27.30	2662	34.0	32.0	28.5	
59 0	24.70	5328	31.5	26.1	12.2	58 0 27.45	2536	34.5	33.0	30.5	
3 5 0	25.50	4496	31.2	26.5	15.6	59 0 27.50	2497	35.2	33.5	30.8	
6 30	25.67	4319	31.2	26.5	15.6	4 0 27.30	2691	35.5	33.6	30.7	
8 0	25.80	4184	33.0	29.1	21.3	1 0 27.30	2691	35.6	33.6	30.5	
9 0	25.85	4128	33.5	29.8	21.9	1 30 27.20	2788	35.7	33.6	30.3	
10 0	25.80	4170	34.5	30.0	22.4	2 0 27.14	2847	35.8	33.1	29.4	
14 0	25.09	4766	32.2	29.1	22.0	3 0 27.25	2744	35.0	33.0	29.8	
15 0	24.92	4909	31.8	27.2	16.6	4 0 27.40	2603	35.5	33.3	30.0	
17 0	24.90	4951	31.0	27.1	16.5	5 0 28.00	2039	36.2	34.8	32.7	
23 0	24.78	5052	30.2	25.1	9.1	6 0 28.25	1804	37.1	35.0	32.3	
24 0	24.72	5122	29.8	25.0	9.8	7 0 28.30	1759	37.3	35.5	33.0	
26 0	24.70	5197	30.2	25.1	8.9	8 0 28.42	1644	38.3	36.5	34.1	
27 0	25.00	4931	30.2	25.2	8.9	8 30 28.50	1569	38.3	37.0	35.2	
32 0	25.50	4489	31.5	28.1	9.6	9 0 28.52	1550	38.7	37.5	35.8	

TABLE II. A.—TWENTY-THIRD ASCENT.—December 1, 1864 (*continued*).

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	°	h m s	in.	feet.	°	°	°
4 10 0	28°60	1475	39°0	38°0	36°7	4 20 0	28°70	1280	42°0	39°7	36°4
13 0	28°70	1381	42°0	40°3	36°8	21 0	28°80	1208	41°2	39°7	37°4
14 0	28°80	1280	42°1	40°2	37°9	21 30	28°82	1194	41°3	39°7	37°2
15 0	28°60	1394	42°0	39°5	36°4	22 0	28°90	1137	41°0	40°2	39°2
15 30	28°50	1451	41°5	39°2	36°3	23 0	29°12	979	41°1	40°2	39°1
17 0	28°35	1532	41°2	38°7	35°5	25 0		} ground {	45°2	43°0	40°5
18 0	28°40	1496	40°5	39°0	37°1	33 0					
19 0	28°50	1424	41°5	39°5	37°0						

B. TWENTY-FOURTH ASCENT.—December 30, 1864.

2 12 0	29°86	ground	42°5	39°0	34°8	2 40 0	29°18	689	35°2	33°5	
13 0	29°80	80	42°1	38°5	34°1	41 0	29°05	1009	35°9	33°8	
14 0	29°51	355	41°0	37°2	32°4	41 30	28°90	1369	36°0	33°9	30°8
15 0	29°25	602	40°0	36°2	31°2	42 0	28°72	1669	35°5	33°8	31°2
15 30	29°05	782	39°0	36°0	32°0	43 0	28°60	1929	35°5	33°5	31°1
16 0	28°95	877	38°2	35°1	30°9	43 30	28°52	2129	35°5	33°2	29°6
16 30	28°80	1020	37°2	34°8	31°5	44 0	28°48	2219	35°5	33°2	29°6
16 45	28°50	1321	36°2	34°2	31°2	45 0	28°32	2689	34°9	32°8	29°4
17 0			...		30°5	45 30	28°30	2699	34°5	33°0	30°5
18 0			...		30°0	46 0	28°26	2829	34°2	32°5	29°6
18 30	27°80	1995	34°1	32°9	30°8	47 0	28°25	2860	34°0	33°0	31°2
19 0	27°60	2220	33°0	32°0	30°0	47 30	28°24	2946	34°0	33°0	31°2
19 30	27°50	2310	32°5	32°0	31°0	48 0	28°40	2796	34°0	33°0	31°2
19 45	27°45	2355	32°7	31°8	30°0	48 30	28°40	2796	34°0	33°0	31°2
20 0	27°40	2410	32°5	31°9	30°7	49 0	28°40	2796	34°0	33°0	31°2
22 0	27°16	2634	32°2	31°5	30°0	49 30	28°45	2666	34°5	33°3	31°2
23 0	27°05	2699	31°9	30°5	27°1	49 45	28°50	2536	35°0	33°2	30°3
23 30	27°05	2699	31°9	30°8	28°3	50 0	28°60	2276	35°3	33°2	29°9
24 0	27°11	2641	31°9	30°5	27°2	50 30	28°68	2070	35°6	33°5	30°3
25 0	27°40	2350	31°9	31°0	28°9	51 0	28°85	1621	35°6	33°5	30°3
26 0	27°45	2301	31°9	31°2	29°6	51 30	28°92	1462	35°6	33°8	31°1
27 0	27°68	2077	31°9	31°6	30°9	51 45	29°00	1256	35°8	33°8	30°8
27 15	27°75	2019	32°3	32°0	30°4	52 0	29°10	1096	36°0	34°0	31°0
28 0	27°55	2215	32°2	32°2	32°2	53 0	29°35	556	36°2	34°0	30°8
28 15	27°40	2362	31°5	31°2	30°4	53 30	29°38	511	36°2	34°5	32°0
28 30	27°21	2552	31°3	30°6	28°9	54 0	29°39	495	36°2	34°5	32°0
29 0	26°92	2822	29°5	29°0	27°3	54 30	29°32	556	36°2	34°5	32°0
29 30	26°71	3018	28°8	28°3	26°4	55 0	29°31	565	36°1	34°5	32°1
29 45			...		27°0	57 0	29°60	299	38°2	36°7	34°7
30 0	26°48	3228	27°5	27°2	26°0	57 30	29°31	570	38°2	36°7	34°7
31 0	26°28	3424	27°2	26°5	23°4	58 30	29°20	670	38°2	35°5	34°9
32 0	26°12	3580	30°0	26°0	13°4	59 0	28°95	900	37°2	36°0	34°4
32 15	26°12	3580	29°5	26°2	15°0	3 0 0	28°78	1056	37°2	36°0	34°4
33 0	26°00	3735	31°5	26°0	12°2	1 0	28°62	1203	37°2	35°7	34°2
34 15	26°15	3589	29°5	26°2	15°1	2 0	28°55	1266	37°2	35°6	33°4
34 30	26°15	3589	29°0	27°2	20°7	2 30	28°60	1216	37°5	35°6	34°0
34 45	26°25	3492	28°2	27°1	22°7	3 0	28°70	1116	37°8	36°2	34°2
35 0	26°50	3249	28°2	27°0	22°3	3 45	29°05	766	37°8	36°2	34°0
35 30	26°20	2570	28°2	28°0	27°3	4 0	29°42	396	38°2	36°4	33°9
36 0	27°65	2133	30°2	29°7	28°3	5 0	29°50	316	38°2	36°4	33°9
37 0	28°90	932	33°0	32°0	30°0	6 0	29°63	186	38°2	36°4	33°9
38 0	28°95	837	34°0	32°5	29°8	15 0	29°82	ground.	38°2	36°5	34°2
39 0	29°05	797	34°5	32°9	30°2						

TABLE II. B.—TWENTY-FOURTH ASCENT.—December 30, 1864 (*continued*).

Time of observation. P.M.			Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.	Time of observation. P.M.			Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h	m	s	in.	feet.	°	°	°	h	m	s	in.	feet.	°	°	°
1	25	0	30.27	ground { 60 176 244 474	47.7	42.4	36.5	2	48	30	27.72	2360	41.2	38.0	34.0
	35	0			47.5	42.0	35.9		49	0	27.75	2330	41.8	38.0	33.3
	52	0	30.20		52.1	45.2	38.0		50	0	27.80	2281	43.0	39.5	35.3
	58	10	30.13		51.8	45.2	38.5		51	0	28.05	2035	43.2	39.0	34.0
	58	20	30.00		51.4	44.8	38.1		54	0	29.31	796	44.2	40.2	35.5
	58	30	29.92	244	51.0	44.1	36.9		55	0	29.80	322	46.2	41.0	35.1
	59	0	29.65	474	49.5	42.1	34.1		56	0	29.65	460	46.2	41.0	35.1
2	0	0	29.30	767	47.2	40.9	33.9		56	30	29.45	644	46.0	41.2	35.7
	1	30	28.98	1085	46.2	40.1	33.2		57	30	29.14	927	44.5	40.0	34.7
	2	0	28.52	1543	45.2	40.1	34.2		58	0	29.11	957	43.5	39.5	34.7
	2	30	28.21	1851	43.7	38.9	33.1		59	0	29.00	1057	43.5	39.0	33.6
	2	45	27.78	2279	41.2	37.1	32.0		59	30	28.90	1148	43.5	38.5	32.6
	3	0					29.0	3	0	0	28.92	1130	43.0	38.5	33.1
	3	30	26.98	3074					1	0	28.98	1075	43.0	38.5	33.1
	4	0	26.72	3333	35.5	33.0	29.1		1	30	28.99	1066	43.5	38.5	33.1
	5	0	26.42	3632	34.8	32.0	27.5		2	0	29.00	1057	43.5	39.0	35.3
	5	30	26.20	3851	34.8	32.0	27.5		3	0	29.07	990	43.5	39.5	34.7
	6	0	26.05	3990	35.0	31.6	27.2		4	0	29.11	953	43.5	39.0	35.3
	6	30	26.00	4040	34.8	30.9	24.7		5	0	29.15	926	43.5	39.3	34.3
	7	30	25.62	4418	34.0	29.2	20.9		5	30	29.50	605	43.5	39.0	33.6
	8	30	25.39	4647	34.0	28.3	18.2		6	0	29.50	605	44.0	39.3	33.8
	9	0	25.34	4697	34.5	28.5	17.1		7	0	29.61	504	44.5	40.0	34.7
	9	30	25.30	4737	35.2	29.0	19.1		8	0	29.63	486	45.0	40.2	34.6
	11	0	25.30	4737	38.2	31.1	21.6		9	0	29.68	441	45.3	40.3	34.6
	11	30	25.25	4795	38.2	30.6	20.3		10	0	29.75	377	45.9	40.5	34.4
	12	0	25.19	4855	38.7	30.6	19.4		11	0	29.80	322	45.5	40.4	34.6
	12	30	25.17	4875	38.7	29.7	17.7		12	0	29.80	322	46.0	41.0	35.3
	13	0	25.17	4875	39.2	29.4	16.5		12	30	29.65	459	46.0	41.0	35.3
	17	0	25.08	4965	39.2	29.2	16.1		13	0	29.32	761	45.2	40.0	34.0
	22	30			38.2	29.0	16.6		14	0	29.30	779	45.2	40.0	34.0
	23	0	25.30	4828	38.2	29.0	16.6		15	30	29.15	916	45.0	40.2	34.6
	24	0	25.30	4828	38.2	29.0	16.6		16	0	29.00	1053	44.2	39.8	34.6
	25	0	25.30	4828	38.2	29.0	16.6		17	0	28.90	1148	43.2	39.0	34.0
	27	0	25.30	4828	38.2	27.5	13.0		17	30	28.90	1148	43.2	39.0	34.0
	27	30	25.25	4840	38.2	27.5	13.0		18	0	28.90	1148	43.2	38.7	33.3
	28	0	25.22	4847	38.1	27.2	12.4		19	0	29.08	978	43.2	38.5	32.9
	29	0	25.20	4865	38.2	27.5	13.0		20	0	29.10	959	43.2	38.5	32.9
	30	0	25.20	4865	38.2	27.5	13.0		21	0	29.30	770	43.2	38.0	31.8
	34	0	25.60	4408	39.2	29.5	16.7		22	0	29.30	770	43.2	38.0	31.8
	34	20	25.60	4408	39.4	30.0	17.7		23	0	29.30	770	43.2	38.1	32.0
	36	0	25.50	4517	39.2	30.0	17.9		24	0	29.33	742	43.1	38.6	33.2
	38	0	25.42	4604	39.2	30.0	17.9		25	0	29.50	582	43.3	39.0	33.9
	40	0	25.30	4734	41.2	31.5	19.3		26	0	29.38	698	43.5	39.0	33.6
	41	0	25.30	4734	41.7	31.3	18.5		27	0	29.20	872	43.5	39.2	34.0
.....					42.0	31.0	17.5		28	0	28.30	969	43.3	39.0	33.9
	42	0	25.50	4538	42.0	31.0	17.5		29	0	28.72	1375	42.5	37.5	31.4
	42	30	25.70	4332	43.2	32.5	19.7		30	0	28.55	1463	42.0	37.3	31.6
	43	0	25.90	4136	43.3	33.0	20.7		30	30	28.25	1689	40.6	36.5	31.2
	44	0	26.60	3450	42.5	35.5	27.0		31	0	28.00	1944	39.6	36.0	
	45	0	26.78	3274	42.0	36.0	28.6		32	0	27.90	2046	38.9	35.5	31.3
	45	30	27.10	2960	41.7	36.0	28.9		32	30	27.80	2148	38.0	35.0	30.9
	46	0	27.35	2715	40.7	35.5	29.0		33	0	27.72	2230	37.9	35.0	31.0
	46	20	27.40	2676	40.5	36.0	30.2		35	0	27.68	2271	37.2	35.0	31.9
	46	30	27.55	2529	41.0	36.5	30.8		37	0	27.50	2455	37.2	34.5	30.7
	47	0	27.70	2382	41.0	37.5	33.1		38	30	27.30	2659	36.5	33.9	30.1
	48	0	27.72	2360	41.0	38.0	34.2		39	0	27.00	2965	36.0	33.5	29.7

TABLE II. B.--TWENTY-FOURTH ASCENT.—December 30, 1864 (*continued*).

Time of observation. P.M.			Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.	Time of observation. P.M.			Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h	m	s	in.	feet.	°	°	°	h	m	s	in.	feet.	°	°	°
3	40	0	26.82	3149	35.2	33.0	29.5	3	51	0	27.71	2252	34.2	33.1	31.2
	41	0	26.82	3149	35.2	33.0	29.5		52	0	28.20	1793	35.5	33.0	29.2
	42	0	26.78	3190	34.2	32.1	28.4		54	0	29.00	1022	42.0	38.0	33.1
	43	0	26.78	3190	34.2	32.2	28.7		55	0	29.30	731	42.5	38.7	34.0
	44	0	26.61	3360	34.2	32.0	28.3		56	0	29.40	634	43.0	39.2	34.6
	45	0	26.45	3521	33.0	32.0	30.0		56	30	29.47	561	43.8	39.5	34.4
	45	30	26.32	3652					57	0	29.56	472	43.7	39.8	35.1
	45	40	26.20	3772	33.0	32.0	30.0		57	30	29.70	448	44.0	40.2	35.7
	46	0	26.52	3415	32.5	32.0	31.0		58	0	29.79	331	44.2	40.6	36.4
	47	0	26.72	3218	32.5	31.7	30.0		59	0	29.80	322	44.4	40.8	36.6
	48	0	26.90	3042	32.5	32.0	31.0		59	30	29.85	70	44.5	40.9	36.7
	49	0	27.30	2650	32.5	32.0	31.0	4	0	0	29.89	ground	44.5	41.2	37.3
	50	0	27.32	2637	33.1	32.7	31.9								

§ 5. VARIATION OF TEMPERATURE OF THE AIR WITH HEIGHT.

Every reading of temperature in the preceding Tables, or the means of small groups of readings when observations have been taken in quick succession at about the same altitude, or when the Balloon has passed and re-passed through nearly the same space within a few minutes—as, for example, on December 1st, between 3^h 44^m and 3^h 49^m it fell from 4464 feet to 3470 feet, and rose to 4170 feet—these readings, or means of readings, were laid down on diagrams, the points joined, and a curved line made to pass through or near them, so that the area of the spaces between the original and the adopted lines on one side was equal to that of the spaces on the other side. Thus treated, temperature decreased with increase of elevation on December 1st and 30th. On February 27th it was found to increase, after attaining the altitude of 4647 feet. On descending, the temperature at first declined, and at 4800 feet the reading was the same as at the same elevation on ascending; then a warm current was met with, and the readings at the same elevation were much higher than were noted in ascending, and continued so through a space of 2800 feet, below which they were lower than on ascending; in consequence of these differences no temperature has been adopted for these, and another ascent and descent were made, for which temperatures have been adopted.

The numbers in the first column show the height in feet, beginning at the ground and increasing upwards; the numbers in the second column show the interval of time in ascending to the highest point; the notes in the third column show the circumstances of the observations; the numbers in the fourth and fifth columns the observed and the approximate normal temperatures of the air; and those in the next column the difference between the two preceding columns, or the most probable effect of the presence of cloud or mist on the temperature, or other local disturbing causes.

The next group of columns is arranged similarly for the descent, and the other groups for succeeding ascents and descents.

TABLE III.—Showing the Temperature of the Air, as read off the curve drawn through the observed temperatures, and as read off the curve of most probable normal temperatures, called adopted temperatures, and the calculated amount of disturbance from the assumed law of decrease of temperature.

TWENTY-THIRD ASCENT.

1864. December 1. Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circum- stances.	Ob- served temp.	Adopted tempe- rature.	Calcu- lated effect of disturb- ance.	Between what times.	Circum- stances.	Ob- served temp.	Adopted tempe- rature.	Calcu- lated effect of disturb- ance.
5400	From 2 ^h 30 ^m to 3 ^h 42 ^m p.m.	Generally clear.	29°3	29°5	— 0°2	From 3 ^h 43 ^m to 4 ^h 33 ^m p.m.	Generally clear.	29°3	29°1	+ 0°2
5200			30°9	30°8	+ 0°1			29°6	29°6	0°0
5000			31°1	31°7	— 0°6			30°0	30°1	— 0°1
4800			32°5	32°8	— 0°3			30°5	30°3	+ 0°2
4600			33°6	33°6	0°0			31°0	30°5	+ 0°5
4400			34°6	35°1	— 0°5			31°4	30°8	+ 0°6
4200			36°9	36°2	+ 0°7			31°8	31°2	+ 0°6
4000			37°0	37°1	— 0°1			32°4	31°7	+ 0°7
3800			38°6	37°9	+ 0°7			32°5	32°1	+ 0°4
3600			39°3	38°6	+ 0°7			32°4	32°4	0°0
3400			39°8	39°2	+ 0°6			32°5	32°7	— 0°2
3200			40°1	39°7	+ 0°4			32°6	33°1	— 0°5
3000			40°3	40°2	+ 0°1			33°0	33°6	— 0°6
2800			40°7	40°8	— 0°1			33°5	34°1	— 0°6
2600			41°2	41°5	— 0°3			35°0	34°5	+ 0°5
2400			42°3	42°2	+ 0°1			35°7	35°0	+ 0°7
2200			43°0	43°0	0°0			36°2	35°7	+ 0°5
2000			43°2	43°7	— 0°5			36°6	36°8	— 0°2
1800			43°8	44°4	— 0°6			37°1	38°0	— 0°9
1600			45°5	45°0	+ 0°5			38°3	38°9	— 0°6
1400			45°8	45°6	+ 0°2			41°6	40°0	+ 1°6
1200			46°2	46°2	0°0			41°2	41°1	+ 0°1
1000			46°8	46°7	+ 0°1			40°9	41°9	— 1°0
800			47°0	47°2	— 0°2			41°7	42°4	— 0°7
600			47°2	47°6	— 0°4			42°6	43°0	— 0°4
400			48°0	47°9	+ 0°1			43°4	43°6	— 0°2
200			48°2	48°0	+ 0°2			45°3	44°3	+ 1°0
0			48°0	48°0	0°0			45°4	45°1	+ 0°3

December 1.—The temperature of the air at the height of 400 feet was the same as on the ground, viz. 48°; on passing above this point the temperature declined to 47 $\frac{1}{4}$ ° at 600 feet, very slowly to 45 $\frac{1}{2}$ ° at 1600 feet; a decrease of 1 $\frac{3}{4}$ ° then took place in the next 200 feet, remained very nearly the same for 400 feet more, and then declined to 41 $\frac{1}{4}$ ° at 2600 feet, still decreasing gradually to 38 $\frac{1}{2}$ ° at 3800 feet, and then rather more quickly to 29 $\frac{1}{4}$ ° at the highest point. On descending, the temperature increased very uniformly till 4000 feet was passed, then almost without change through a decline of 800 feet, or to 3200 feet high; increased 1° in the next 400 feet downwards, and 1 $\frac{1}{2}$ ° in the succeeding 200 feet; after this the temperature increased by pretty even amounts, till the height of 1800 feet was reached; here a warm current was entered, for by the time the balloon had descended to 1400 feet, the temperature had increased to 41 $\frac{1}{2}$ °; it then declined to 41° at 1000 feet,

after which it increased by even amounts till within 200 feet of elevation, where the temperature was $45^{\circ}3$, being only $0^{\circ}1$ less than that found on the ground.

TABLE III. (continued.)

TWENTY-FOURTH ASCENT.

1864. December 30	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temperature.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temperature.	Calculated effect of disturbance.
		Just out of cloud.	o	o	o			o	o	o
2600	From 2 ^h 12 ^m to 2 ^h 33 ^m 30 ^s p.m.	Entered cloud.	32°3	32°0	+ 0°3	From 2 ^h 24 ^m to 2 ^h 27 ^m 15 ^s p.m.	Approaching cloud.	31°8	31°8	0°0
2400		Approaching cloud.	32°5	32°5	0°0			31°9	31°9	0°0
2200		Misty.	33°0	33°1	- 0°1			32°0	32°0	0°0
2000			34°1	33°8	+ 0°3			32°5	32°5	0°0
1800			34°8	34°8	0°0			The balloon then turned to ascend.		
1600			35°6	35°6	0°0					
1400			36°1	36°1	0°0					
1200			36°9	36°9	0°0					
1000			37°8	37°6	+ 0°2					
800			39°0	39°0	0°0					
600	From 2 ^h 32 ^m to 2 ^h 32 ^m 15 ^s p.m.	Above cloud, sun dazzlingly bright.	40°0	39°9	+ 0°1	From 2 ^h 33 ^m to 2 ^h 39 ^m p.m.	Above cloud. In very dense cloud.	29°0	29°3	- 0°3
400			40°9	40°9	0°0			28°4	28°4	0°0
200			41°6	41°6	0°0			28°4	28°4	0°0
0			42°6	42°6	0°0			28°4	28°4	0°0
3600			29°6	29°5	+ 0°1			28°3	28°3	0°0
3400			27°1	27°4	- 0°3			28°2	28°2	0°0
3200			27°7	27°7	0°0			28°2	28°2	0°0
3000			28°8	28°6	+ 0°2			28°2	28°2	0°0
2800			29°5	29°6	- 0°1			28°2	28°2	0°0
2600			31°0	30°6	+ 0°4			28°2	28°5	- 0°3
2400	From 2 ^h 28 ^m to 2 ^h 32 ^m 15 ^s p.m.	Just entering cloud.	31°2	31°3	- 0°1		Out of cloud.	29°0	29°1	- 0°1
2200			32°2	32°2	0°0			30°0	29°8	+ 0°2
2000			32°5	33°1	- 0°6			30°6	30°6	0°0
1800								31°1	31°1	0°0
1600								31°6	31°6	0°0
1400								32°1	32°1	0°0
1200								32°5	32°5	0°0
1000								33°0	33°1	- 0°1
800								34°2	34°2	0°0
								The balloon then turned to ascend.		

TABLE III. (*continued.*)
 TWENTY-FOURTH ASCENT (*continued.*)

1864. Dec. 30 (<i>con.</i>) Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circum- stances.	Ob- served temp.	Adopted temp.	Calcu- lated effect of disturb- ance.	Between what times.	Circum- stances.	Ob- served temp.	Adopted tempe- rature.	Calcu- lated effect of disturb- ance.
2800	From 2 ^h 40 ^m to 2 ^h 47 ^m 30 ^s p.m.	Under cloud.	°	°	°	From 2 ^h 48 ^m to 2 ^h 57 ^m p.m.	Under cloud.	°	°	°
2600			34°3	34°4	-0°1			34°0	34°3	-0°3
2400			35°0	34°9	+0°1			35°0	35°0	0°0
2200			35°4	35°3	+0°1			35°1	35°2	-0°1
2000			35°5	35°3	+0°2			35°3	35°3	0°0
1800			35°6	35°6	0°0			35°3	35°4	-0°1
1600			35°6	35°6	0°0			35°5	35°5	0°0
1400			35°6	35°6	0°0			35°6	35°6	0°0
1200			36°0	35°8	+0°2			35°7	35°7	0°0
1000			36°0	36°0	0°0			35°9	35°8	+0°1
800	From 2 ^h 57 ^m 30 ^s to 3 ^h 2 ^m p.m.	Below cloud.	36°0	36°0	0°0	From 3 ^h 2 ^m 30 ^s to 3 ^h 14 ^m p.m.	Below cloud.	36°0	35°9	+0°1
600			35°9	35°9	0°0			36°1	36°1	0°0
400								36°3	36°4	-0°1
								37°5	37°2	+0°3
								The balloon then turned to ascend.		
1200			37°2	37°2	0°0			37°7	37°6	+0°1
1000			37°2	37°4	-0°2			37°7	37°7	0°0
800			37°7	37°7	0°0			37°3	37°9	-0°1
600			38°2	38°0	+0°2			38°0	38°0	0°0
400			38°2	38°3	-0°1			38°2	38°2	0°0
200								38°3	38°3	0°0
0								38°4	38°5	-0°1

December 30.—The temperature of the air was $42\frac{1}{2}^{\circ}$ on the ground; it declined 1° in the first 200 feet; $0^{\circ}7$ in the second; $0^{\circ}9$ in the third; $1^{\circ}0$ in the fourth; $1^{\circ}2$ in the fifth, where it was $37^{\circ}8$, or nearly 5° less than on the ground; it then decreased by amounts varying from $\frac{1}{2}^{\circ}$ to 1° in every 200 feet, till 2400 feet had been passed, where the temperature was $32\frac{1}{2}^{\circ}$, declining to $32\frac{1}{3}^{\circ}$ at 2600 feet. The balloon then turned to descend, the temperature remaining at nearly the same value, viz. 32° , for 400 feet, and increased $\frac{1}{2}^{\circ}$ on falling to 2000 feet, when the balloon turned to ascend, the temperature decreasing very evenly up to 3400 feet: here a warm current was met with; for the temperature increased $2\frac{1}{2}^{\circ}$ in passing from 3400 feet to 3600 feet, the temperature there being $29\frac{1}{2}^{\circ}$. On descending, the temperature decreased to $28\frac{1}{2}^{\circ}$ at 3400 feet, and remained very nearly at that value for the next 800 feet, but increased to 29° at 2400 feet and to 30° at 2200 feet; after this it increased about $\frac{1}{2}^{\circ}$ for every 200 feet, till the balloon had fallen to 1000 feet, and $1\frac{1}{4}^{\circ}$ whilst passing from that to 800 feet; the balloon then turned to re-ascend for the second time, the temperature remaining at 36° whilst passing upward from 800 feet to 1400 feet; it then declined about $\frac{1}{2}^{\circ}$ in passing through the next 200 feet, and remained nearly at that value till 2400 feet were reached, and fell to $34\frac{1}{4}^{\circ}$ at 2800 feet, when the balloon turned to descend, the temperature increasing from 34° at 2800 feet to $38^{\circ}2$ at 300 feet; on again ascending, the temperature did not vary until 600 feet was reached, but declined to $37^{\circ}2$ at 1200 feet, and gradually increased to $38^{\circ}4$ on the ground.

TABLE III. (*continued.*)

TWENTY-FIFTH ASCENT.

1865. February 27.		Temperature of the Air.								
		Ascending.				Descending.				
Height, in feet, above the mean level of the sea.	Between what times.	Circum- stances.	Ob- served temp.	Adopted tempe- rature.	Calcu- lated effect of disturb- ance.	Between what times.	Circum- stances.	Ob- served temp.	Adopted tempe- rature.	Calcu- lated effect of disturb- ance.
5000	From 1 ^h 52 ^m p.m. to 2 ^h 17 ^m p.m.	Above Cloud.	39°4	33°4	+6°0	From 2 ^h 22 ^m 30 ^s to 3 ^h 12 ^m p.m.	On a level with cloud. Below the level of the cloud.	39°0	°	°
4800			38°3	33°1	+5°2			38°4		
4600			34°0	33°2	+0°8			39°5		
4400		In cloud.	34°0	33°4	+0°6			42°1		
4200			34°3	33°6	+0°7			43°3		
4000			35°0	33°8	+1°2			43°1		
3800			34°8	34°1	+0°7			43°0		
3600			34°8	34°5	+0°3			42°8		
3400			35°1	35°1	0°0			42°5		
3200			35°8	35°8	0°0			42°0		
3000			37°2	36°9	+0°3			41°7		
2800			38°0	37°8	+0°2			41°7		
2600		Below cloud.	39°4	38°7	+0°7			41°2		
2400			40°4	39°6	+0°8			42°0		
2200			41°5	40°7	+0°8			43°0		
2000			42°8	41°7	+1°1			43°2		
1800			43°9	42°8	+1°1			43°2		
1600			44°9	43°7	+1°2			43°2		
1400			45°5	44°6	+0°9			43°2		
1200			45°8	45°6	+0°2			43°2		
1000			46°5	46°6	-0°1			43°6		
800			47°0	47°7	-0°7			43°7		
600			48°7	48°9	-0°2			45°3		
400			49°9	50°0	-0°1			45°7		
200			51°3	51°1	+0°2					
0			52°3	52°3	0°0					
3600	From 3 ^h 12 ^m 30 ^s to 3 ^h 45 ^m 40 ^s p.m.	In cloud.	33°6	33°5	+0°1			From 3 ^h 46 ^m to 4 ^h p.m.	In cloud.	32°7
3400			33°9	34°0	-0°1	32°6	32°8			-0°2
3200			34°2	34°8	-0°6	32°6	32°9			-0°3
3000		35°7	35°4	+0°3	32°6	33°0	-0°4			
2800		In haze.	36°2	35°9	+0°3	32°6	33°1		-0°5	
2600			36°7	36°5	+0°2	32°7	33°3		-0°6	
2400			37°2	37°2	0°0	33°5	33°5		0°0	
2200			37°8	38°0	-0°2	34°4	34°0		+0°4	
2000		Below cloud.	38°9	38°9	0°0	Below cloud.	34°8		34°8	0°0
1800			40°0	39°8	+0°2		35°2		36°0	-0°8
1600			41°1	40°6	+0°5		37°0		37°2	-0°2
1400			42°3	41°4	+0°9		38°9		38°5	+0°4
1200			43°0	42°3	+0°7		40°4		39°9	+0°5
1000			43°7	43°2	+0°5		42°0		41°4	+0°6
800			44°3	44°0	+0°3		42°6		42°7	-0°1
600			44°9	44°8	+0°1		43°2		43°4	-0°2
400	45°7		45°7	0°0	44°1		44°1	0°0		
200					44°5		44°5	0°0		
0					44°5		44°5	0°0		

February 27.—The temperature on the ground was 52°·3, which declined 1° on passing through the first 200 feet, and about 1½° in each space of

200 feet up to 800 feet, where the temperature was 47° or $5^{\circ}3$ lower than on the ground: the decline was then less rapid, for on passing through the next 800 feet the whole decrease was $2^{\circ}1$. The temperature then declined rather more rapidly to $35^{\circ}1$ at 3400 feet high; at 3600 feet it was $34\frac{3}{4}^{\circ}$, and varied but little from this till 4000 feet had been passed; it then decreased to 34° at 4600 feet, when it suddenly became warm, the temperature increasing to $38\frac{3}{4}^{\circ}$ on passing above 4800 feet, and to $39\frac{1}{2}^{\circ}$ nearly on reaching 5000 feet, the same temperature having been passed at 2600 feet. The balloon then turned to descend, the temperature at first decreasing to $38^{\circ}4$ at 4800 feet, being the same as noted on ascending: here a warm current was met with, and the temperature increased rapidly; when at 4200 feet it was $43^{\circ}3$, being 9° warmer than was noticed at the same elevation on ascending; this excess gradually diminished, till at about 2000 feet high the temperature observed during the descent was very nearly the same as noted during the ascent; and below this the temperatures were all lower by some degrees than were recorded at the same elevation during the ascent: these differences seem to be chiefly owing to the presence of cloud situated between 3100 feet and 4100 feet high, or 1000 feet in thickness passed through in ascending, and seen at the same level, but not passed through in descending. The point where the temperatures noted were the same ascending and descending was a little below the cloud-plane; at lower elevations, to the ground, the air was some degrees warmer under the cloud, during the ascent, than in the absence of cloud during the descent. The effect of the presence of the cloud in this ascent seems to have been to cool the air several degrees; and this cooling influence seems to have extended for nearly 1000 feet above the cloud, and for 500 or 600 feet below; nearer the earth the presence of the cloud seems to have exercised a warming influence. In the descent it will be seen that the temperature differed very little from 43° , from 4200 feet high to 1000 feet high, the depression to $41^{\circ}+$ from 3000 feet to 2600 feet being evidently influenced by the passage through the cloud-plane. On ascending again, first haze was passed through, then cloud entered, giving readings differing but little from those met with in the first ascent. On descending to the earth, temperatures a little lower, owing apparently to the diurnal decrease of temperature at these altitudes, were met with, thus far agreeing with those during the first ascent; and comparison with those during the first descent through a large break in the clouds gives a great deal of information upon the large influence exercised by the presence of cloud.

In previous Reports a Table (No. IV.) was formed here, showing the decrease of temperature in every 1000 feet; as no additional information at high elevations is given this year, this Table has not been formed. The results of Table V. of preceding years are included in Table III. of this year.

TABLE VI.—Showing the Decrease of Temperature with every

Height, in feet, above the level of the sea.		Dec. 1, 1864.		Dec. 30, 1864.							
		State of the Sky.									
		Generally clear.		Cloudy.							
				Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.
From	To	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.
feet.	feet.	o	o	o	o	o	o	o	o	o	o
4900	5000	0'5	0'1	..	..	..	..	..	..	..	..
4800	4900	0'6	0'1	..	..	..	..	..	..	..	..
4700	4800	0'4	0'1	..	..	..	..	..	..	..	..
4600	4700	0'4	0'1	..	..	..	..	..	..	..	..
4500	4600	0'7	0'1	..	..	..	..	..	..	..	..
4400	4500	0'8	0'2	..	..	..	..	..	..	..	..
4300	4400	0'5	0'2	..	..	..	..	..	..	..	..
4200	4300	0'6	0'2	..	..	..	..	..	..	..	..
4100	4200	0'5	0'2	..	..	..	..	..	..	..	..
4000	4100	0'4	0'3	..	..	..	..	..	..	..	..
3900	4000	0'4	0'2	..	..	..	..	..	..	..	..
3800	3900	0'4	0'2	..	..	..	..	..	..	..	..
3700	3800	0'4	0'2	..	..	..	..	..	..	..	..
3600	3700	0'3	0'1	..	..	..	..	..	..	..	..
3500	3600	0'3	0'1	..	..	+1'0	+0'4	..	..	..	..
3400	3500	0'3	0'2	..	..	+1'1	+0'5	..	..	..	..
3300	3400	0'3	0'2	..	..	0'1	0'0	..	..	..	..
3200	3300	0'2	0'2	..	..	0'3	0'0	..	..	..	..
3100	3200	0'2	0'2	..	..	0'4	0'0	..	..	..	..
3000	3100	0'3	0'3	..	..	0'5	+0'1	..	..	..	..
2900	3000	0'3	0'3	..	..	0'5	+0'1	..	..	..	..
2800	2900	0'3	0'2	..	..	0'5	0'0	..	..	..	..
2700	2800	0'3	0'2	..	..	0'5	0'1	0'2	0'3	..	..
2600	2700	0'4	0'2	..	..	0'5	0'2	0'3	0'4	..	..
2500	2600	0'4	0'2	0'2	0'0	0'4	0'3	0'2	0'1	..	..
2400	2500	0'3	0'3	0'3	0'1	0'3	0'3	0'2	0'1	..	..
2300	2400	0'4	0'3	0'3	0'1	0'4	0'3	0'0	0'1	..	..
2200	2300	0'4	0'4	0'3	0'0	0'5	0'4	0'0	0'0	..	..
2100	2200	0'4	0'5	0'3	0'2	0'4	0'4	0'1	0'0	..	..
2000	2100	0'3	0'6	0'4	0'3	0'5	0'4	0'2	0'1	..	..
1900	2000	0'3	0'6	0'5	..	..	0'3	0'0	0'1	..	..
1800	1900	0'4	0'6	0'5	..	..	0'2	0'0	0'0	..	..
1700	1800	0'3	0'5	0'4	..	..	0'2	0'0	0'0	..	..
1600	1700	0'3	0'4	0'4	..	..	0'3	0'0	0'1	..	..
1500	1600	0'3	0'5	0'3	..	..	0'3	0'1	0'1	..	..
1400	1500	0'3	0'6	0'2	..	..	0'2	0'1	0'0	..	..
1300	1400	0'3	0'6	0'4	..	..	0'2	0'1	0'0	..	..
1200	1300	0'3	0'5	0'4	..	..	0'2	0'1	0'1	..	..
1100	1200	0'3	0'4	0'4	..	..	0'3	0'0	0'1	0'1	0'0
1000	1100	0'2	0'4	0'3	..	..	0'3	0'0	0'0	0'1	0'1
900	1000	0'2	0'3	0'7	..	..	0'5	+0'1	0'1	0'1	0'1
800	900	0'3	0'2	0'7	..	..	0'6	0'0	0'1	0'2	0'1
700	800	0'2	0'3	0'5	..	..	..	..	0'1	0'1	0'1
600	700	0'2	0'3	0'4	..	..	..	..	0'2	0'2	0'0
500	600	0'2	0'3	0'5	..	..	..	..	0'4	0'1	0'1
400	500	0'1	0'3	0'5	..	..	..	..	0'4	0'2	0'1
300	400	0'1	0'3	0'4	..	..	..	..	..	..	0'1
200	300	0'0	0'4	0'3	..	..	..	..	..	..	0'0
100	200	0'0	0'4	0'5	..	..	..	..	..	..	0'1
0	100	0'0	0'4	0'5	..	..	..	..	..	..	0'1

No. of col. 1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

crease of 100 feet up to 5000 feet.

Feb. 27, 1865.			Mean.			General mean (omitting July 17, 1862, August 31, 1863, January 12, April 6, July 13, 20, 27, 1864, and February 27, 1865).						
State of the Sky.												
Cloudy.			Cloudy.	Number of experi- ments.	Clear.	Number of experi- ments.	Cloudy.			Clear.		
Ascending.	Ascending.	Descending.					Mean.	Number of experi- ments.	Space passed through for a decline of 1°.	Mean.	Number of experi- ments.	Space passed through for a decline of 1°.
0	0	0	0	..	0	2	0	20	feet.	0		feet.
0	0	0	0	..	0	2	0	20	333	0	12	333
0	0	0	0	..	0	2	0	20	333	0	12	333
0	0	0	0	..	0	2	0	20	333	0	12	333
0	0	0	0	..	0	2	0	21	333	0	12	333
0	0	0	0	..	0	2	0	21	333	0	12	333
0	0	0	0	..	0	2	0	24	333	0	12	333
0	0	0	0	..	0	2	0	24	333	0	12	333
0	0	0	0	..	0	2	0	24	333	0	14	333
0	0	0	0	..	0	2	0	25	333	0	14	333
0	0	0	0	..	0	2	0	25	333	0	14	333
0	0	0	0	..	0	2	0	26	333	0	14	333
0	0	0	0	..	0	2	0	27	333	0	13	333
0	0	0	0	..	0	2	0	27	333	0	13	333
0	0	0	0	..	0	2	0	28	333	0	13	333
0	0	0	0	..	0	2	0	28	333	0	13	333
0	0	0	0	..	0	2	0	30	333	0	13	333
0	0	0	0	..	0	2	0	31	333	0	12	333
0	0	0	0	..	0	2	0	30	250	0	12	333
0	0	0	0	..	0	2	0	31	250	0	12	333
0	0	0	0	..	0	2	0	31	250	0	12	333
0	0	0	0	..	0	2	0	34	250	0	12	333
0	0	0	0	..	0	2	0	34	250	0	12	333
0	0	0	0	..	0	2	0	37	250	0	12	333
0	0	0	0	..	0	2	0	37	250	0	12	333
0	0	0	0	..	0	2	0	36	250	0	12	333
0	0	0	0	..	0	2	0	36	250	0	12	333
0	0	0	0	..	0	2	0	36	250	0	12	333
0	0	0	0	..	0	2	0	36	250	0	12	333
0	0	0	0	..	0	2	0	34	250	0	12	333
0	0	0	0	..	0	2	0	34	250	0	12	333
0	0	0	0	..	0	2	0	36	250	0	12	333
0	0	0	0	..	0	2	0	36	250	0	12	333
0	0	0	0	..	0	2	0	38	250	0	13	250
0	0	0	0	..	0	2	0	38	250	0	13	250
0	0	0	0	..	0	2	0	35	250	0	10	250
0	0	0	0	..	0	2	0	35	250	0	10	200
0	0	0	0	..	0	2	0	37	250	0	10	200
0	0	0	0	..	0	2	0	37	250	0	10	200
0	0	0	0	..	0	2	0	33	250	0	10	200
0	0	0	0	..	0	2	0	33	250	0	10	200
0	0	0	0	..	0	2	0	29	250	0	10	200
0	0	0	0	..	0	2	0	29	250	0	10	200
0	0	0	0	..	0	2	0	27	200	0	10	200
0	0	0	0	..	0	2	0	27	200	0	10	250
0	0	0	0	..	0	2	0	24	200	0	10	250
0	0	0	0	..	0	2	0	24	200	0	10	200
0	0	0	0	..	0	2	0	24	200	0	10	200
0	0	0	0	..	0	2	0	24	167	0	10	167
13.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.

§ 6. VARIATION OF THE HYGROMETRIC CONDITION OF THE AIR WITH ELEVATION.

All the adopted readings of the temperature of the dew-point in Section 4 were laid down on diagrams, and joined by lines drawn from one to the other. In the case of the temperature of the air, when thus joined, a curved line can be drawn through them, giving equal weight to every observation; but this cannot be done with respect to the temperature of the dew-point, it being far more variable than the temperature of the air; and the numbers in the following Table are those read at every 200 feet, from the diagram formed simply by joining the points of observation.

TABLE VII.—Showing the Variation of the Hygrometric condition of the Air at every 200 feet of Height.

TWENTY-THIRD ASCENT.

1864. December 1. Height, in feet, above the mean level of the sea.	Humidity of the Air.									
	Ascending.					Descending.				
	Between what times.	Circum- stances.	Tempe- rature of the dew- point.	Elastic force of vapour.	Degree of humi- dity.	Between what times.	Circum- stances.	Tempe- rature of the dew- point.	Elastic force of vapour.	Degree of humi- dity.
			°	in.				°	in.	
5400			15°0	·086	53			15°3	·087	54
5200			13°0	·078	45			16°9	·093	57
5000			12°1	·074	42			18°4	·100	60
4800			14°4	·083	45			18°5	·100	58
4600			17°8	·097	50			18°7	·101	59
4400			20°4	·110	55			19°1	·103	59
4200			22°0	·118	54			19°3	·104	58
4000			23°7	·127	57			19°6	·106	57
3800			25°7	·139	59			17°5	·096	52
3600			28°5	·156	65			15°9	·089	48
3400			29°3	·162	66			19°4	·105	58
3200			29°6	·164	66			23°0	·123	66
3000			29°6	·164	66			26°7	·145	86
2800			29°6	·164	62			27°9	·152	79
2600			30°1	·168	65			30°5	·170	83
2400			35°0	·204	76			30°9	·173	83
2200			37°6	·225	81			31°4	·176	82
2000			36°9	·219	79			31°8	·179	82
1800			36°5	·216	76			32°5	·184	83
1600			36°9	·219	72			34°7	·201	87
1400			37°1	·221	72			36°8	·218	83
1200			37°6	·225	72			37°2	·222	86
1000			38°6	·234	73			39°0	·238	93
800			38°8	·236	73			39°3	·240	91
600			38°5	·233	75			39°5	·242	89
400			39°5	·242	72			39°9	·246	88
200			39°5	·242	72			40°2	·249	82
0			40°0	·247	74			40°5	·252	83

December 1.—The temperature of the dew-point on the ground before starting was 40°, or 8° below that of the air; this difference slightly increased to 8 $\frac{2}{3}$ ° at 1600 feet, when the air became more moist, the temperature of the air at 2200 feet being 43°, and that of the dew-point 37 $\frac{1}{2}$ °; these temperatures then separated suddenly, the difference between them at 2600 feet being rather more than 11°; this difference remained about the same until 3600 feet were passed, when it began to increase quickly up to 5000 feet, where it was 19°, the temperatures of the air and dew-point being 31°·1 and 12°·1 respectively, the degree of humidity being as low as 42. The air then became somewhat more moist, and the degree of humidity increased to 53 at 5400 feet; at 5000 feet, on descending, the temperature of the air was 30°, and that of the

dew-point $18^{\circ} \cdot 4$, showing a difference of $11^{\circ} \cdot 6$, which increased gradually to $12^{\circ} \cdot 3$ at 4000 feet; the air then suddenly became much drier, the degree of humidity being 48 at 3600 feet, and the difference between the temperatures of the air and dew-point was $16^{\circ} \cdot 5$. The air then became much more moist, and continued so till the ground was reached. The most humid state was experienced at the height of 1000 feet from the earth.

TABLE VII. (*continued*).
TWENTY-FOURTH ASCENT.

1864. December 30.	Humidity of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
2600	From 2 ^h 12 ^m to 2 ^h 30 ^m 30 ^s p.m.	Just out of cloud.	30°0	in. 167	91	From 2 ^h 24 ^m to 2 ^h 27 ^m 15 ^s p.m.	Approaching cloud.	27°2	in. 148	83
2400		Entered cloud.	30°7	172	94			28°6	137	76
2200		Approaching cloud.	30°0	167	89			30°2	168	93
2000		Misty.	30°8	172	88			30°5	170	92
1800			30°9	173	86			The balloon then turned to ascend.		
1600			31°0	174	84					
1400			31°1	174	82					
1200			31°3	176	81					
1000			31°4	176	77					
800			31°6	178	75					
600			31°5	177	72					
400			32°2	182	71					
200			33°5	192	73					
0			34°9	203	74					
3600	From 2 ^h 28 ^m to 2 ^h 32 ^m 15 ^s p.m.	Above cloud, sun dazzlingly bright.	14°4	083	51	From 2 ^h 33 ^m to 2 ^h 39 ^m p.m.	Above cloud. In very dense cloud.	18°0	098	62
3400			23°6	127	86			22°6	121	78
3200		In dense cloud.	26°0	141	94		Out of cloud.	22°9	122	92
3000			26°5	144	91			24°4	131	85
2800		Just entering cloud.	27°5	150	92			25°6	139	91
2600			28°7	158	91			27°1	148	96
2400			30°1	168	96			27°6	151	95
2200			32°2	182	100			28°4	156	94
2000			30°5	170	92			28°7	158	92
1800								29°0	160	92
1600								20°1	160	90
1400								29°4	162	90
1200								29°8	166	90
1000								30°0	167	89
800								30°0	167	85
								The balloon then turned to ascend.		

TABLE VII. (*continued*).
 TWENTY-FOURTH ASCENT (*continued*).

1864. Dec. 30 (<i>cont.</i>)	Humidity of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
2800	From 2 ^h 40 ^m to 2 ^h 47 ^m 20 ^s p.m.	Below cloud.	29°8	in. .166	84	From 2 ^h 48 ^m to 2 ^h 57 ^m p.m.	Below cloud.	30°0	in. .167	85
2600			29°5	.163	80			30°4	.170	83
2400			29°8	.166	80			30°1	.168	83
2200			29°7	.165	80			30°1	.168	82
2000			30°0	.167	80			30°5	.170	83
1800			30°9	.173	83			30°5	.170	82
1600			31°2	.175	84			30°5	.170	82
1400			30°7	.172	81			30°5	.170	82
1200			30°7	.172	81			30°9	.173	82
1000			30°7	.172	81			30°7	.172	81
800	From 2 ^h 57 ^m 30 ^s to 3 ^h 2 ^m p.m.	Below cloud.	30°8	.172	82	From 3 ^h 2 ^m 30 ^s to 3 ^h 15 ^m p.m.	Below cloud.	30°2	.168	79
600			...	...	...			29°6	.164	77
400			...	...	...			33°5	.192	86
								The balloon then turned to ascend.		
1200			34°5	.199	90			34°1	.196	87
1000			34°6	.200	90			34°0	.196	87
800			34°9	.203	91			33°8	.194	86
600			35°0	.204	89			33°9	.195	85
400			35°0	.204	89			33°8	.194	84
200			...	...	...			33°6	.193	84
0			...	...	...			34°4	.199	86

December 30.—The temperature of the dew-point on the ground was 34°·9, and the humidity 74, the former decreasing to 31½° at 600 feet, where the humidity was 72; the dew-point then varied but little, and much less than the temperature of the air, so that the degree of humidity increased to the height of 2400 feet, then was smaller at 2600 feet. The balloon descended then to 2000 feet, then turned to ascend; the air continued humid till 3200 feet was passed; the degree of humidity at this point was 94; above this point the air was much drier. During the subsequent successive ascents and descents the air in the lower atmosphere was found to be very humid.

February 27.—The temperature of the dew-point on the earth was 38°, or 14°·3 below that of the air, the air being consequently unusually dry, and particularly so for February, the degree of humidity being 59 only. On ascending, the air gradually became more moist, till the height of 3200 feet in the centre of cloud, where the degree of humidity was 78. On leaving the cloud below, the air became drier, and was the driest at 5000 feet high, where it was 37. On descending, the air was much drier down to 2600 feet than at corresponding heights during the ascent. No cloud was passed through, and at lower elevations the air was more moist than in the ascent. On ascending again through cloud, and descending also through cloud, the results were very similar to those noted in the first ascent, the most humid states being those in the cloud, which in the last descent were found but little short of saturation.

TABLE VII. (*continued.*)

TWENTY-FIFTH ASCENT.

1865. February 27.		Humidity of the Air.									
		Ascending.					Descending.				
Height, in feet, above the mean level of the sea.	Between what times.	Circum- stances.	Tempe- rature of the dew- point.	Elastic force of vapour.	Degree of humi- dity.	Between what times.	Circum- stances.	Tempe- rature of the dew- point.	Elastic force of vapour.	Degree of humi- dity.	
5000	From 1 ^h 52 ^m to 2 ^h 17 ^m p.m.	Above cloud.	0	in.		From 2 ^h 22 ^m 30 ^s to 3 ^h 12 ^m p.m.		0	in.		
4800			15.8	.089	37			15.8	.089	37	
4600			20.0	.108	47			16.4	.091	39	
4400			18.3	.099	51			18.1	.098	41	
4200		In cloud.	18.5	.100	52			19.4	.105	39	
4000			22.0	.118	60			20.5	.110	41	
3800			26.7	.145	71			21.8	.117	42	
3600			27.5	.150	74			23.7	.127	46	
3400			27.6	.151	75			25.5	.138	50	
3200			28.7	.158	77			27.4	.149	55	
3000			29.3	.162	78		On a level with clouds.	28.6	.157	59	
2800			29.6	.164	74			28.8	.158	60	
2600		Below cloud.	29.7	.165	72		Below the level of cloud.	29.0	.160	61	
2400			30.0	.167	69			30.4	.170	66	
2200			31.2	.175	69			32.6	.185	69	
2000			32.2	.182	69			34.9	.203	73	
1800			32.7	.186	68			33.9	.195	70	
1600			33.3	.190	66			33.8	.194	70	
1400			33.8	.194	65			33.7	.193	69	
1200			33.8	.194	64			33.5	.192	69	
1000			33.4	.191	62			33.4	.191	69	
800			33.4	.191	60			34.5	.199	70	
600			33.7	.193	60			34.0	.196	69	
400			34.0	.196	57			34.4	.199	66	
200			34.7	.201	57			35.3	.206	67	
0			37.6	.225	60			The balloon then turned to ascend.			
			38.0	.229	59						
3600	From 3 ^h 12 ^m 30 ^s to 4 ^h 45 ^m 40 ^s p.m.	In cloud.	30.0	.167	87	From 3 ^h 46 ^m to 4 ^h 0 ^m p.m.	In cloud.	30.5	.170	91	
3400			28.6	.157	81			30.9	.173	94	
3200			28.5	.156	80			30.2	.168	91	
3000			29.7	.165	79			31.0	.174	94	
2800		In haze.	30.0	.167	78		In cloud.	31.0	.174	94	
2600			30.3	.169	78			31.9	.180	97	
2400			31.0	.174	79			31.4	.176	92	
2200			30.9	.173	77			31.0	.174	87	
2000			31.3	.176	74		Below cloud.	30.1	.168	83	
1800			31.2	.175	71			29.2	.161	79	
1600			31.3	.176	68			30.0	.167	78	
1400			31.4	.176	65			31.0	.174	74	
1200		32.0	.181	66	32.0			.181	72		
1000		32.7	.186	65	33.1			.188	71		
800		33.4	.191	66	33.8			.194	71		
600		34.0	.196	66	34.4			.199	72		
400		34.8	.202	66	36.0			.212	74		
200					36.6			.217	74		
0					37.3			.223	76		

The numbers in this Table having been found from experiments taken at different times in the year, and under different circumstances from those in previous years, can scarcely be combined with them, till we know more about

the general laws at the different seasons of the year. I defer for the present making any further use of them, particularly as their combination would not change the general Tables previously found.

TABLE VIII.—Showing the Degree of Humidity at every 200 feet.

Height above the level of the sea.	Dec. 1, 1864.		December 30, 1864.								February 27, 1865.			Mean.					
	State of the Sky.																		
	Generally Clear.		Cloudy.								Cloudy.	Generally Cloudy.		Cloudy.	Cloudy.	Number of experiments.	Clear.	Number of experiments.	
	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.					
feet.																			
5400	53	54	...	...	...	...	...	...	...	...	...	...	...	...	...	...	53	2	
5200	45	57	...	...	...	...	...	...	...	...	...	...	...	...	...	...	51	2	
5000	42	60	...	...	...	...	...	...	...	...	37	37	...	...	...	37	2	51	2
4800	45	58	...	...	...	...	...	...	...	...	47	39	...	...	...	43	2	51	2
4600	50	59	...	...	...	...	...	...	...	...	51	41	...	...	...	46	2	54	2
4400	55	59	...	...	...	...	...	...	...	...	52	39	...	...	...	46	2	57	2
4200	54	58	...	...	...	...	...	...	...	...	60	41	...	...	...	50	2	56	2
4000	57	57	...	...	...	...	...	...	...	...	71	42	...	...	...	56	2	57	2
3800	59	52	...	...	...	...	...	...	...	...	74	46	...	...	...	60	2	55	2
3600	65	48	...	...	51	62	...	...	...	...	75	50	87	91	69	6	56	2	
3400	66	58	...	...	86	78	...	...	...	...	77	55	81	94	78	6	62	2	
3200	66	66	...	...	94	92	...	...	...	...	78	59	80	91	82	6	66	2	
3000	66	86	...	...	91	85	...	...	...	...	74	60	79	94	80	6	76	2	
2800	62	79	...	...	92	91	84	85	...	...	72	61	78	94	82	8	70	2	
2600	65	83	91	83	91	96	80	83	...	...	69	66	78	97	83	10	74	2	
2400	76	83	94	76	96	95	80	83	...	...	69	69	79	92	82	10	79	2	
2200	81	82	89	93	100	94	80	82	...	...	69	73	77	87	84	10	81	2	
2000	79	82	88	92	92	92	80	83	...	...	68	70	74	83	82	10	80	2	
1800	76	83	86	...	...	92	83	82	...	...	66	70	71	79	79	8	80	2	
1600	72	87	84	...	...	90	84	82	...	...	65	69	68	78	77	8	79	2	
1400	72	83	82	...	...	90	81	82	...	...	64	69	65	74	76	8	78	2	
1200	72	86	81	...	...	90	81	82	90	87	62	69	66	72	78	10	79	2	
1000	73	93	77	...	...	89	81	81	90	87	60	70	65	71	77	10	83	2	
800	73	91	75	...	...	85	82	79	91	86	60	69	66	71	76	10	82	2	
600	75	89	72	...	...	...	...	77	89	85	57	66	66	72	73	8	82	2	
400	72	88	71	...	...	...	...	76	89	84	57	67	66	74	73	8	80	2	
200	72	82	73	...	...	...	...	...	...	84	50	...	...	74	72	4	77	2	
0	74	83	74	...	...	...	...	...	...	86	59	...	...	76	72	4	78	2	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19.

The numbers in this Table show, as in all similar experiments at all times in the year, that the moisture in the air is very different at the same elevation at different times; and that the moisture on the same day was differently distributed over different places. The most remarkable in this Table is that of the first descent on February 27, the balloon having ascended through clouds, descended through a break in the clouds, and then ascended and descended again through clouds, showing a marked difference at the same elevation in the degree of humidity of the air. These results are too few, and having been deduced from experiments made at a different season of the year from those previously made, had better be left till more winter ascents have been made to combine with them.

§ 7. COMPARISON OF THE TEMPERATURE OF THE DEW-POINT, AS DETERMINED BY DIFFERENT INSTRUMENTS AND METHODS, AND COMPARISON OF THEIR RESULTS TOGETHER.

TABLE IX.—Showing the Temperature of the Dew-point, as determined at about the same height by different instruments and methods, and comparison of the results together.

Under 1000 feet.

| Date. | | | Height. | Dew-point temperatures. | | | | Temperature of the dew-point as determined by | | | | | |
|-------|----|---|---------|-------------------------|--------------------------|-----------------------|------------------------|---|-----------------------|------------------------|---------------------------------------|------------------------|--|
| | | | | Calculated from | | Observed by | | Dry and Wet (free) above that by | | | Dry and Wet (aspirated) above that by | | |
| | | | | Dry and Wet (free). | Dry and Wet (aspirated). | Daniell's Hygrometer. | Regnault's Hygrometer. | Dry and Wet (aspirated). | Daniell's Hygrometer. | Regnault's Hygrometer. | Daniell's Hygrometer. | Regnault's Hygrometer. | Daniell's Hygrometer above that by Regnault's. |
| | d | h | m | feet. | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| Dec. | 1 | 0 | 0 | ground | 40.4 | .. | 40.2 | .. | +0.2 | 0 | 0 | 0 | 0 |
| | | 1 | 15 | ground | 39.1 | .. | 40.0 | .. | -0.9 | | | | |
| | | 2 | 30 | ground | 40.0 | .. | 40.0 | 40.0 | 0.0 | 0.0 | | | |
| Dec. | 30 | 2 | 55 | 565 | 32.1 | .. | 32.5 | .. | .. | -0.4 | | | |
| Feb. | 27 | 1 | 52 | ground | 38.0 | .. | 34.2 | .. | .. | +3.8 | | | |
| | | 2 | 58 | 957 | 34.7 | .. | 35.0 | .. | -0.3 | | | | |
| | | 3 | 6 | 605 | 33.8 | .. | 34.0 | .. | -0.2 | | | | |
| | | 3 | 10 | 377 | 34.4 | .. | 32.0 | .. | .. | +2.4 | | | |
| | | 3 | 14 | 779 | 34.0 | .. | 34.0 | .. | 0.0 | | | | |
| | | 3 | 24 | 742 | 33.2 | .. | 34.0 | .. | -0.8 | | | | |

From 1000 to 2000 feet.

| | | | | | | | | | | | | | |
|------|----|---|------------------|------|------|----|----|------|----|----|------|--|--|
| Dec. | 30 | 2 | 51 $\frac{3}{4}$ | 1256 | 30.8 | .. | .. | 30.5 | .. | .. | +0.3 | | |
| Feb. | 27 | 3 | 18 | 1148 | 33.3 | .. | .. | 33.0 | .. | .. | +0.3 | | |

From 2000 to 3000 feet.

| | | | | | | | | | | | | | |
|------|----|---|----|------|------|----|------|------|----|------|------|--|--|
| Dec. | 1 | 3 | 57 | 2662 | 28.5 | .. | 28.0 | .. | .. | +0.5 | | | |
| | | 4 | 0 | 2691 | 30.7 | .. | 30.0 | .. | .. | +0.7 | | | |
| Dec. | 30 | 2 | 22 | 2634 | 30.0 | .. | 28.0 | .. | .. | .. | +2.0 | | |
| | | 2 | 44 | 2219 | 29.6 | .. | 30.0 | .. | .. | -0.4 | | | |
| Feb. | 27 | 2 | 47 | 2382 | 33.1 | .. | .. | 33.0 | .. | .. | +0.1 | | |
| | | 2 | 49 | 2330 | 33.3 | .. | 34.0 | .. | .. | -0.7 | | | |
| | | 3 | 35 | 2271 | 31.9 | .. | 30.5 | .. | .. | +1.4 | | | |

TABLE IX. (*continued*).
From 3000 to 4000 feet.

| Date. | | | | Height. | Dew-point temperatures. | | | | Temperature of the dew-point as determined by | | | | | | |
|-------|------|----|----|---------|-------------------------|--------------------------|-----------------------|------------------------|---|-----------------------|------------------------|---------------------------------------|------------------------|--|---|
| | | | | | Calculated from | | Observed by | | Dry and Wet (free) above that by | | | Dry and Wet (aspirated) above that by | | Daniell's Hygrometer above that by Regnault's. | |
| | | | | | Dry and Wet (free). | Dry and Wet (aspirated). | Daniell's Hygrometer. | Regnault's Hygrometer. | Dry and Wet (aspirated). | Daniell's Hygrometer. | Regnault's Hygrometer. | Daniell's Hygrometer. | Regnault's Hygrometer. | | |
| Dec. | d | h | m | feet. | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| | 1 | 3 | 46 | 3470 | 22.5 | .. | 21.5 | .. | .. | +1.0 | ° | ° | ° | ° | ° |
| | | 3 | 52 | 3744 | 20.0 | .. | 20.0 | .. | .. | 0.0 | | | | | |
| Dec. | | 3 | 54 | 3240 | 24.7 | .. | 25.0 | .. | .. | -0.3 | | | | | |
| | 30 | 2 | 33 | 3735 | 12.2 | .. | 15.0 | 14.0 | .. | -2.8 | -1.8 | | | | |
| | Feb. | 27 | 3 | 45 | 3521 | 30.0 | .. | 30.5 | .. | .. | -0.5 | | | | |
| | | 3 | 46 | 3415 | 31.0 | .. | 30.7 | .. | .. | +0.3 | | | | | |
| | | 3 | 48 | 3042 | 31.0 | .. | .. | 30.5 | .. | .. | +0.5 | | | | |

From 4000 to 5000 feet.

| | | | | | | | | | | | | | |
|------|----|---|-----|------|------|----|------|------|----|------|------|--|--|
| Dec. | 1 | 2 | 50 | 4222 | 23.8 | .. | 20.0 | .. | .. | +3.8 | | | |
| | | 3 | 5 | 4496 | 15.6 | .. | 15.0 | .. | .. | +0.6 | | | |
| | | 3 | 14 | 4766 | 22.0 | .. | 16.0 | .. | .. | +6.0 | | | |
| | | 3 | 17 | 4951 | 16.5 | .. | 19.0 | .. | .. | -2.5 | | | |
| Feb. | 27 | 3 | 49 | 4170 | 15.0 | .. | .. | 15.0 | .. | .. | 0.0 | | |
| | | 2 | 7½ | 4418 | 20.9 | .. | 18.5 | .. | .. | +2.4 | | | |
| | | 2 | 11 | 4737 | 21.6 | .. | .. | 19.0 | .. | .. | +2.6 | | |
| | | 2 | 17 | 4965 | 16.1 | .. | 15.0 | .. | .. | +1.1 | | | |
| | | 2 | 27 | 4828 | 13.0 | .. | .. | 15.0 | .. | .. | -2.0 | | |
| | | 2 | 34 | 4408 | 16.7 | .. | 17.0 | .. | .. | -0.3 | | | |
| | | 2 | 34½ | 4408 | 17.7 | .. | .. | 16.0 | .. | .. | +1.7 | | |

From 5000 to 6000 feet.

| | | | | | | | | | | | | | |
|------|---|---|----|------|------|----|------|----|----|------|--|--|--|
| Dec. | 1 | 2 | 58 | 5328 | 12.2 | .. | 17.0 | .. | .. | -4.8 | | | |
|------|---|---|----|------|------|----|------|----|----|------|--|--|--|

TABLE X.

| Heights between | | Excess of Temperature of the Dew-point as determined by Dry and Wet Thermometers (free) above that observed by | | | |
|-----------------|----------|--|-------------|------------------------|-------------|
| | | Daniell's Hygrometer. | No. of obs. | Regnault's Hygrometer. | No. of obs. |
| feet. | feet. | | | | |
| ° | and 1000 | -0.3 | 7 | +1.4 | 4 |
| 1000 | „ 2000 | .. | .. | +0.3 | 2 |
| 2000 | „ 3000 | +0.5 | 5 | +1.0 | 2 |
| 3000 | „ 4000 | -0.4 | 6 | -0.6 | 2 |
| 4000 | „ 5000 | +1.6 | 7 | +0.6 | 4 |
| 5000 | „ 6000 | -4.8 | 1 | | |

TABLE XI.—Simultaneous readings of a delicate blackened-bulb thermometer fully exposed to the sun's rays, and of a delicate thermometer carefully shaded from the influence of the sun, the bulbs of the two instruments being within 3 inches of each other.

December 1, 1864.

| Time of observation. | Height above mean sea-level. | Temperature of | | Excess of reading of Blackened-bulb Thermometer. | Remarks. |
|----------------------|------------------------------|---------------------|-----------------------------|--|-----------------------|
| | | Shaded Thermometer. | Blackened-bulb Thermometer. | | |
| h m s | feet. | | | | |
| | ground. | 46°2 | 56°0 | +9°8 | Sun shining. |
| 1 15 0 p.m. | ground. | 46°8 | 56°0 | +9°2 | |
| 2 39 0 " | 890 | 47°2 | 47°0 | -0°2 | Sun shining brightly. |
| 41 0 " | 1618 | 45°0 | 44°5 | -0°5 | Sun shining brightly. |
| 46 0 " | 3570 | 39°5 | 40°0 | +0°5 | Sun warm. |
| 51 0 " | 4324 | 38°0 | 39°0 | +1°0 | |
| 55 0 " | 4742 | 35°0 | 35°5 | +0°5 | |
| 3 5 0 " | 4496 | 31°2 | 33°0 | +1°8 | |
| 9 0 " | 4128 | 33°5 | 29°5 | -4°0 | |
| 14 0 " | 4766 | 32°2 | 31°5 | -0°7 | |
| 17 0 " | 4951 | 31°0 | 31°0 | 0°0 | |
| 24 0 " | 5122 | 29°8 | 30°0 | +0°2 | |
| 48 0 " | 3973 | 33°0 | 33°0 | 0°0 | |

December 30, 1864.

| | | | | | |
|--------------|------|------|------|-----|--|
| 2 34 30 p.m. | 3589 | 29°0 | 29°0 | 0°0 | |
| 39 0 " | 797 | 34°5 | 34°5 | 0°0 | |
| 42 0 " | 1669 | 35°5 | 35°5 | 0°0 | |
| 43 0 " | 1929 | 35°5 | 35°5 | 0°0 | |

February 27, 1865.

| | | | | | |
|-------------|--------|------|------|------|----------------------|
| 1 58 0 p.m. | ground | .. | 52°0 | | |
| 58 20 " | 176 | 51°4 | 52°0 | +0°6 | |
| 59 0 " | 474 | 49°5 | 51°5 | +2°0 | |
| 2 6 30 " | 4040 | 34°8 | 35°0 | +0°2 | Sun shining faintly. |
| 28 0 " | 4847 | 38°1 | 38°3 | +0°2 | |
| 40 0 " | 4734 | 41°2 | 45°0 | +3°8 | |
| | .. | 42°0 | 43°5 | +1°5 | Sun hot to sense. |
| 42 0 " | 4332 | 42°0 | 43°5 | +1°5 | |
| 45 0 " | 3274 | 42°0 | 42°5 | +0°5 | |
| 49 0 " | 2330 | 41°8 | 41°0 | -0°8 | |
| 56 30 " | 644 | 46°0 | 46°0 | 0°0 | |

December 1, 1864.

Observations of the time of vibration of Evans's Magnet and Glaisher's Magnet.

| 1864. | Place of observation. | Height above sea-level. | Evans's and Glaisher's Magnet. | | | | | Magnet. |
|--------------|-----------------------|-------------------------|--------------------------------|----------------------------|-------------------|---------|---|-----------|
| | | | No. of vibrations in each set. | Time occupied in each set. | Arc of vibration. | | Mean time of vibration from each set of observations. | |
| | | | | | At commencement. | At end. | | |
| h m | | feet. | | s | ° | ° | s | |
| Dec. 1. 2 48 | In Balloon. | 3600 | 28 | 45.2 | .. | .. | 1.614 | Glaisher. |
| 2 52 | " | 4200 | 50 | 119.5 | 60 | 5 | 2.390 | Evans. |
| 2 56 | " | 4800 | 20 | 50.0 | 100 | .. | 2.500 | " |
| 2 56+ | " | 4800 | 28 | 68.4 | 120 | .. | 2.553 | " |
| 3 1 | " | 5000 | 34 | 56.2 | 40 | .. | 1.653 | Glaisher. |
| 3 2 | " | 5000 | 10 | 23.2 | 10 | .. | 2.320 | Evans. |
| 3 7 | " | 4100 | 30 | 50.5 | 80 | .. | 1.683 | Glaisher. |
| 3 12 | " | 4300 | 40 | 93.3 | 60 | .. | 2.333 | Evans. |
| 3 16 | " | 4900 | 20 | 42.2 | 10 | .. | 2.110 | " |
| 3 20 | " | 5000 | 52 | 123.8 | 90 | 1 | 2.381 | " |
| 3 30 | " | 4500 | 10 | 24.1 | 100 | .. | 2.410 | " |
| 3 37 | " | 5000 | 58 | 140.0 | 100 | .. | 2.414 | " |
| 3 47 | " | 3600 | 20 | 47.3 | 90 | .. | 2.365 | " |
| 12 0 | Blackheath. | 160 | 80 | 165.2 | 50 | .. | 2.065 | " |
| | " | .. | 60 | 124.4 | 50 | .. | 2.073 | " |
| | " | .. | 38 | 55.0 | 50 | .. | 1.448 | Glaisher. |
| | " | .. | 40 | 67.2 | 50 | .. | 1.680 | " |
| | " | .. | 20 | 32.2 | 50 | .. | 1.610 | " |
| Dec. 2. | Royal Observatory. | 160 | 30 | 59.0 | 25 | 3 | 1.967 | Evans. |
| | " | .. | 10 | 19.8 | 27 | 5 | 1.980 | " |
| | " | .. | 40 | 81.9 | 113 | 38 | 2.047 | " |
| | " | .. | 20 | 40.2 | 40 | 8 | 2.010 | " |
| | " | .. | 10 | 15.3 | 80 | 2 | 1.530 | Glaisher. |
| | " | .. | 30 | 47.3 | 160 | 30 | 1.577 | " |
| | " | .. | 20 | 31.8 | 150 | 6 | 1.590 | " |
| | " | .. | 10 | 15.5 | 140 | 10 | 1.550 | " |
| | " | .. | 20 | 31.3 | 150 | 50 | 1.565 | " |
| 1865. | | | | | | | | |
| Feb. 27. | In Balloon. | 4900 | 40 | 89.9 | 100 | 20 | 2.247 | Evans. |
| | " | 4800 | 38 | 87.7 | 150 | 50 | 2.307 | " |
| | South Hanningfield. | 110 | 50 | 100.1 | 150 | 10 | 2.002 | " |
| | " | .. | 50 | 100.0 | 140 | 10 | 2.000 | " |

HEIGHTS AND APPEARANCE OF THE CLOUDS.

December 1, 1864.

Before starting the sky was cloudy.

At 3^h 50^m p.m., at 3968 feet, the setting sun illuminated the topmost part of a dark stratus cloud with a very deep orange-colour; not a cloud in the sky above altitude 15°.

December 30, 1864.

At 2^h 15^m p.m., at 602 feet. Misty all round.

At 2^h 19^m 45^s p.m., at 2355 feet. Approaching cloud.

At 2^h 21^m p.m., at 2532 feet. Entered cloud.

At 2^h 23^m 30^s p.m., at 2699 feet. Just out of cloud.

At 2^h 28^m p.m., at 2215 feet. Approaching cloud.

At 2^h 28^m 30^s p.m., at 2552 feet. Just entering cloud.

At 2^h 28^m 45^s p.m., at 2687 feet. Passed into cloud and lost sight of everything.

At 2^h 30^m p.m., at 3228 feet. Cloud dense and cold.

At 2^h 31^m p.m., at 3424 feet. The sky was of a beautiful prussian-blue colour, with a beautiful sea of cloud below of varied surface, bright and shining.

At 2^h 34^m 40^s p.m., at 3550 feet. In a very dense cloud.

At 2^h 35^m 30^s p.m., at 2570 feet. Out of cloud below.

February 27, 1865.

At 2^h 3^m 30^s p.m., at 3074 feet. In cloud.

At 2^h 4^m p.m., at 3333 feet. In a white cloud.

At 2^h 5^m 30^s p.m., at 3850 feet. We are in cloud: the clouds below are moving much more quickly than we are.

At 2^h 7^m 30^s p.m., at 4418 feet. The clouds below appear to be moving N.

At 2^h 8^m 30^s p.m., at 4647 feet. The clouds below are moving at right angles to us.

At 2^h 9^m 30^s p.m., at 4737 feet. Clouds have a very fine purple tinge over a very beautiful even surface.

At 2^h 27^m 30^s p.m., at 4840 feet. Clouds very high above us.

At 2^h 45^m p.m., at 3274 feet. Clouds on our level.

At 3^h 1^m 30^s p.m., at 1075 feet. Upper clouds moving as before.

At 3^h 38^m 30^s p.m., at 2659 feet. In haze.

At 3^h 39^m p.m., at 2965 feet. In thicker haze.

At 3^h 40^m p.m., at 3149 feet. In cloud.

At 3^h 41^m p.m., at 3149 feet. Still in cloud.

At 3^h 43^m p.m., at 3190 feet. Misty.

At 3^h 44^m 30^s p.m., at 3440 feet. In cloud.

At 3^h 45^m p.m., at 3521 feet. In fog.

At 3^h 46^m p.m., at 3415 feet. In cloud.

At 3^h 49^m p.m., at 2650 feet. Out of cloud.

DIRECTION OF THE WIND.

December 1, 1864.

On the ground the wind was from the W.N.W., light and variable.

On the ground at 1^h 15^m p.m., a pilot balloon first moved W., and afterwards N.W.

At 2^h 40^m p.m., at 1230 feet. The balloon entered a S.W. current.
 At 2^h 57^m p.m., at 5038 feet. The wind was W.N.W.
 At 3^h 33^m p.m., at 4541 feet. Smoke near the earth moving S., but after reaching 1000 feet, moving N.
 At 3^h 56^m p.m., at 2830 feet. The wind was W.N.W. The smoke below moved S.

February 27, 1865.

On the ground before starting the wind was from the S.
 At 2^h 1^m 30^s p.m., at 1543 feet. The wind was S.W.
 At 2^h 7^m 30^s p.m., at 4418 feet. The wind was W.
 At 2^h 25^m p.m., at 4828 feet. Entered a more southerly current, about S.W.
 At 3^h 32^m 30^s p.m., at 2148 feet. Changed direction, moving W., I think.

ON THE PROPAGATION OF SOUND.

December 1, 1864.

At 3^h 49^m p.m., at 4170 feet. Heard voices.
 At 3^h 58^m p.m., at 2536 feet. Heard a clock strike 4^h plainly.
 At 4^h 6^m p.m., at 1804 feet. Heard many voices.
 At 4^h 7^m p.m., at 1759 feet. Can hear cries of "come down."

February 27, 1865.

At 2^h 1^m p.m., at 877 feet. Bells sound very clearly.

GENERAL OBSERVATIONS.

December 1, 1864.

At 2^h 38^m 30^s p.m., at 644 feet. A gun fired; felt the shock.
 At 2^h 39^m 30^s p.m., at 890 feet. Sun shining brightly.
 At 2^h 42^m p.m., at 1831 feet. Report of proving guns at Woolwich; perceptible vibration; every rope vibrating; and every instrument shaking.
 At 2^h 43^m p.m., at 2248 feet. Opened the valve; nearly opposite Belvedere.
 At 2^h 46^m p.m., at 3570 feet. Sun warm.
 At 2^h 54^m p.m., at 4630 feet. Between Erith and Belvedere.
 At 2^h 59^m p.m., at 5328 feet. Nearly opposite Erith; hills and dales distinctly visible.
 At 3^h 9^m p.m., at 4128 feet. Sand out.
 At 3^h 15^m p.m., at 4909 feet. A little to the right, or nearly over Dartford.
 At 3^h 17^m p.m., at 4951 feet. Moving towards Cobham Park.
 At 3^h 33^m p.m., at 4541 feet. South of Greenhithe.
 At 3^h 34^m p.m., at 4805 feet. In a line with Northfleet; we shall pass over Cobham Park.
 At 3^h 46^m p.m., at 3470 feet. A chill to sense; sand thrown out.
 At 3^h 52^m p.m., at 3744 feet. A sudden chill again.
 At 3^h 53^m p.m., at 3744 feet. Sand thrown out.
 At 3^h 59^m p.m., at 2497 feet. Sand again thrown out.

- At 4^h 1^m p.m., at 2691 feet. Saw a railway train.
 At 4^h 2^m p.m., at 2847 feet. A great deal of moisture on the balloon.
 At 4^h 3^m p.m., at 2744 feet. Nearly south of Gravesend.
 At 4^h 8^m p.m., at 1644 feet. Cobham Park.
 At 4^h 9^m p.m., at 1550 feet. Moist to sense.
 At 4^h 13^m p.m., at 1381 feet. Moisture almost dropping from the balloon.
 At 4^h 14^m p.m., at 1280 feet. Approaching the Medway.
 At 4^h 15^m p.m., at 1394 feet. Ascending to a higher current to cross the river.
 At 4^h 17^m p.m., at 1532 feet. We can see Rochester Bridge and Castle.
 At 4^h 33^m p.m. On the ground at Delce Farm near Rochester.

December 30, 1864.

- At 2^h 16^m 30^s p.m., at 1020 feet. Cold.
 At 2^h 19^m 30^s p.m., at 2310 feet. Dropped the grapnel.
 At 2^h 23^m 30^s p.m., at 2699 feet. Just over the wall of the river.
 At 2^h 24^m p.m., at 2641 feet. At least 150 vessels in sight.
 At 2^h 26^m p.m., at 2301 feet. Our course is taking each bight of the river.
 At 2^h 27^m 15^s p.m., at 2019 feet. Sand out.
 At 2^h 28^m p.m., at 2215 feet. Cold to sense.
 At 2^h 29^m p.m., at 2822 feet. Very cold.
 At 2^h 29^m 45^s p.m., at 3128 feet. Much lighter; very cold.
 At 2^h 32^m 15^s p.m., at 3580 feet. Sun brighter.
 At 2^h 34^m p.m., at 3610 feet. Sun obscured in mist.
 At 2^h 34^m 40^s p.m., at 3522 feet. In a very dense cloud.
 At 2^h 36^m p.m., at 2133 feet. Falling quickly, revolving in two minutes.
 At 2^h 38^m p.m., at 837 feet. We are about a mile north of Purfleet.
 At 2^h 41^m 30^s p.m., at 1369 feet. Moving towards Sea Reach.
 At 2^h 58^m 30^s p.m., at 670 feet. Sand thrown out.
 At 3^h 3^m p.m., at 1116 feet. Moving direct for Sea Reach; we must come down if we do not change our direction.
 At 3^h 6^m p.m., at 186 feet. Packed up all the instruments, cleared the tops of some trees, and came down within a mile of the river, near the Railway Station at Stanford-le-Hope.
 At 3^h 10^m p.m. On the ground.

February 27, 1865.

- At 1^h 58^m p.m. We left the earth.
 At 2^h p.m., at 767 feet. Over the river.
 At 2^h 1^m 30^s p.m., at 1085 feet. Sun obscured by cloud.
 At 2^h 2^m 30^s p.m., at 1851 feet. Moving towards Barking Creek.
 At 2^h 3^m 30^s p.m., at 3074 feet. Cold.
 At 2^h 5^m p.m., at 3632 feet. Faint gleams of light.
 At 2^h 5^m 30^s p.m., at 3851 feet. Over water.
 At 2^h 6^m 30^s p.m., at 4040 feet. Sun shining faintly.
 At 2^h 9^m 30^s p.m., at 4737 feet. Over Barking level; Tilbury line to our left, or N.
 At 2^h 11^m p.m., at 4737 feet. Sensibly warmer.
 At 2^h 12^m 30^s p.m., at 4875 feet. Over Dagenham Marsh.
 At 2^h 24^m p.m., at 4828 feet. Lowered grapnel.
 At 2^h 25^m p.m., at 4828 feet. Entered a more southerly current about S.W.
 At 2^h 34^m p.m., at 4408 feet. Must come down.

At 2^h 36^m p.m., at 4517 feet. Sun again bright.
 At 2^h 37^m p.m., at 4580 feet. Moving along Sea Reach.
 At 2^h 41^m 30^s p.m., at 4600 feet. Sun hot.
 At 2^h 42^m p.m., at 4538 feet. Opened valve.
 At 3^h 5^m p.m., at 926 feet. Neck of balloon tied up.
 At 3^h 29^m p.m., at 1375 feet. 12 miles from Chelmsford.
 At 3^h 38^m p.m., at 2560 feet. Water looks like polished steel.
 At 3^h 38^m 30^s p.m., at 2659 feet. Country brightened up by the sun.
 At 3^h 39^m p.m., at 2965 feet. We have only one bag of ballast.
 At 3^h 45^m 30^s p.m., at 3652 feet. Opened valve; only one bag of ballast left.
 At 3^h 59^m 30^s p.m., at 70 feet. Just over some trees.
 At 4^h 1^m p.m. On the ground at South Hanningfield.

Meteorological Observations made in connexion with the Balloon Ascent on

December 1, 1864.—ROYAL OBSERVATORY, GREENWICH.

| Time of observation. | Reading of | | Temp. of the dew-point. | Ten-sion of va-pour. | Degree of humi-dity. | Direc-tion of wind. | Amount of cloud 0-10. | Amount of ozone. | Remarks. |
|----------------------|--------------------------|--------------------|-------------------------|----------------------|----------------------|---------------------|-----------------------|------------------|--|
| | Barom. reduced to 32° F. | Thermom. Dry. Wet. | | | | | | | |
| h m | in. | ° ° | ° | in. | | | | | |
| Noon. | 30°003 | 46°5 43°9 | 40°9 | 256 | 82 | W.S.W. | 0 | 0 | Cloudless; slight haze in N. and S. |
| 0 15 p.m. | 30°004 | 46°7 44°0 | 40°9 | 256 | 81 | W.S.W. | 0 | 0 | |
| 0 30 " | 30°001 | 46°7 43°5 | 40°5 | 252 | 80 | W.S.W. | 0 | 0 | |
| 0 45 " | 30°004 | 47°1 44°2 | 40°9 | 256 | 80 | W.S.W. | 0 | 0 | |
| 1 0 " | 30°005 | 47°3 44°3 | 41°0 | 257 | 79 | S.W. | 0 | 0 | Cloudless; dense haze in the direction of Woolwich. |
| 1 15 " | 30°006 | 47°3 44°5 | 41°4 | 261 | 81 | W.S.W. | 0 | 0 | |
| 1 30 " | 30°006 | 47°3 44°5 | 41°4 | 261 | 81 | W.S.W. | 0 | 0 | |
| 1 45 " | 30°005 | 47°3 44°3 | 41°0 | 257 | 79 | W.S.W. | 0 | 0 | Cloudless. Haze is gradually clearing off, and a few light clouds are rising in the N. |
| 2 0 " | 30°002 | 47°3 44°3 | 41°0 | 257 | 79 | W.S.W. | 1 | 0 | Light cirrus in the N. |
| 2 15 " | 30°001 | 46°8 44°0 | 40°8 | 255 | 80 | W.S.W. | 2 | 0 | Light high cirrus in N. and N.N.E. |
| 2 30 " | 30°002 | 46°3 43°6 | 40°5 | 252 | 81 | W.S.W. | 4 | 0 | Light cirrus scattered about the sky. |
| 2 45 " | 30°002 | 46°3 43°5 | 40°4 | 251 | 81 | W.S.W. | 4 | 0 | |
| 3 0 " | 30°002 | 46°0 43°5 | 40°7 | 254 | 82 | S.W. | 4 | 0 | Balloon rising in E.S.E. Lost to view at 3 ^h 8 ^m , apparently falling. |
| 3 20 " | 30°015 | 44°3 42°8 | 41°0 | 257 | 89 | S.W. | 1 | 0 | Light cirrus in S.W.; haze. |
| 3 30 " | 30°021 | 44°3 42°5 | 40°4 | 251 | 96 | S.W. | 0 | 0 | Cloudless, with the exception of a little cirrostratus in S.W.; slight haze. |
| 3 45 " | 30°024 | 44°0 42°3 | | | | S.W. | 0 | 0 | Cloudless, with the exception of a little cirrostratus in the horizon. |
| 4 0 " | 30°026 | 43°6 41°9 | | | | S.W. | 0 | 0 | Cloudless. |
| 4 15 " | 30°029 | 43°4 41°7 | | | | S.W. | 0 | 0 | |
| 4 30 " | 30°033 | 43°3 41°4 | | | | S.W. | 0 | 0 | |

Meteorological Observations made in connexion with the Balloon Ascent on

December 30, 1864.—ROYAL OBSERVATORY, GREENWICH.

| Time of observation. | | Reading of | | Temp. of the dew-point. | Ten-sion of va-pour. | Degree of humi-dity. | Direc-tion of wind. | Amount of cloud 0-10. | Amount of ozone | Remarks. | |
|----------------------|--------|--------------------------|----------|-------------------------|----------------------|----------------------|---------------------|-----------------------|-----------------|----------|--|
| | | Barom. reduced to 32° F. | Thermom. | | | | | | | | |
| | | | Dry. | | | | | | | | Wet. |
| h | m | in. | ° | ° | ° | in. | | | | | |
| 1 | 0 p.m. | 29.788 | 38.8 | 36.1 | 32.5 | .184 | 79 | S.W. | 10 | 0 | Generally overcast; clouds broken. |
| 1 | 15 " | 29.785 | 38.8 | 36.2 | 32.7 | .186 | 80 | S.W. | 10 | 0 | |
| 1 | 30 " | 29.784 | 38.7 | 36.0 | 32.4 | .184 | 79 | S.W. | 10 | 0 | |
| 1 | 45 " | 29.781 | 38.6 | 36.0 | 32.5 | .184 | 79 | S.W. | 10 | 0 | |
| 2 | 0 " | 24.781 | 38.5 | 35.8 | 32.3 | .183 | 78 | S.W. | 10 | 0 | |
| 2 | 15 " | 29.777 | 38.5 | 35.9 | 32.5 | .184 | 79 | S.W. | 10 | 0 | |
| 2 | 30 " | 29.775 | 38.4 | 36.1 | 33.0 | .188 | 82 | S.W. | 10 | 0 | |
| 2 | 45 " | 29.770 | 38.6 | 36.1 | 32.7 | .186 | 80 | S.W. | 10 | 0 | |
| 3 | 0 " | 29.760 | 38.6 | 36.1 | 32.7 | .186 | 80 | S.W. | 10 | 0 | |
| 3 | 15 " | 29.759 | 38.4 | 35.9 | 32.5 | .184 | 80 | S.W. | 10 | 0 | |
| 3 | 30 " | 29.757 | 38.2 | 35.9 | 32.9 | .187 | 81 | S.W. | 10 | 0 | |
| 3 | 45 " | 29.818 | 38.1 | 35.5 | 32.0 | .181 | 79 | S.W. | 10 | 0 | Very dense clouds in S.; cirrus elsewhere generally. |
| 4 | 0 " | 29.744 | 37.4 | 35.2 | 32.2 | .182 | 82 | S.W. | 7 | 0 | |

February 27, 1865.—ROYAL OBSERVATORY, GREENWICH.

| | | | | | | | | | | |
|----------|--------|------|------|------|------|----|------------|----|---|--|
| 1 0 p.m. | 30.017 | 48.6 | 43.4 | 37.7 | .226 | 66 | S.W. | 10 | 0 | |
| 1 15 " | 30.019 | 48.9 | 43.3 | 37.2 | .222 | 65 | S.S.W. | 10 | 0 | |
| 1 30 " | 30.014 | 49.0 | 42.9 | 36.2 | .214 | 62 | S. | 10 | 0 | Light cirrocumulus and a little stratus in S.W. horizon. Haze in N. |
| 1 45 " | 30.008 | 48.7 | 43.0 | 36.8 | .218 | 63 | S.W. | 10 | 0 | Cirrus, and cirrocumulus in the zenith. Dense cirrostratus and cumulostratus in horizon, gradually spreading over the sky. |
| 2 0 " | 29.997 | 47.4 | 42.2 | 36.4 | .215 | 66 | S. by W. | 10 | 0 | Cirrus; clear sky in the zenith; cumulus and cumulostratus. |
| 2 15 " | 29.995 | 47.9 | 43.1 | 37.8 | .227 | 69 | S.S.W. | 10 | 0 | Dense clouds almost entirely cover the sky. Balloon first seen at 2 ^h ; and was visible for about 4 ^m ; seen due E., and appeared moving in a northerly direction. |
| 2 30 " | 29.991 | 47.4 | 42.2 | 36.4 | .215 | 66 | S.W. | 10 | 0 | Sky generally covered with dense clouds, excepting a little clear in the zenith. |
| 2 45 " | 28.988 | 47.1 | 42.4 | 37.1 | .221 | 68 | S.S.W. | 10 | 0 | " " " |
| 3 0 " | 29.980 | 46.8 | 42.4 | 37.5 | .225 | 70 | S.W. by S. | 10 | 0 | " " " |
| 3 15 " | 29.975 | 46.3 | 42.1 | 37.2 | .222 | 72 | S.W. by S. | 10 | 0 | Generally overcast; clouds broken slightly in the air. |
| 3 30 " | 29.967 | 46.1 | 42.0 | 37.3 | .223 | 72 | S.S.W. | 10 | 0 | Clear sky and light cirrus in the zenith; dense clouds in the N. |
| 3 45 " | 29.965 | 45.9 | 42.0 | 37.5 | .225 | 73 | S.W. | 10 | 0 | Generally overcast, with the exception of a little clear in the S.E. |
| 4 0 " | 29.968 | 45.6 | 41.6 | 37.0 | .220 | 73 | S.W. by W. | 10 | 0 | Uniformly covered with cirrostratus. |

Interim Report of the Committee on the Transmission of Sound under Water, consisting of the Rev. Dr. ROBINSON, Prof. WHEATSTONE, Dr. GLADSTONE, and Prof. HENNESSY.

WHEN the Committee on Fog-signals stated at the Meeting of the British Association last year that no success had attended their efforts to induce the Board of Trade to undertake experiments on the subject, it was thought advisable to change the mode of procedure. The Parliamentary Committee was requested to press on the Government the expediency of instituting such experiments, while the Committee was reappointed for the purpose of making experiments on the transmission of sound under water—a line of inquiry suggested by us in our memorial to the President of the Board of Trade, June 18, 1863. The sum of £30 was placed at our disposal, and to this the Government-Grant Committee of the Royal Society have added £100.

The subject of the production of sound under water, and its transmission through that medium, had previously engaged the attention of one of our number, Professor Wheatstone, and we naturally wished to be guided in our first trials by his experience. A long and serious illness unfortunately delayed the commencement of that gentleman's experiments; but the investigation has been fairly begun this summer. The results hitherto arrived at are instructive and promising, but they are not sufficiently precise to warrant their publication. We have therefore only to report progress, and to ask the British Association to give us the opportunity of bringing our results before them next year.

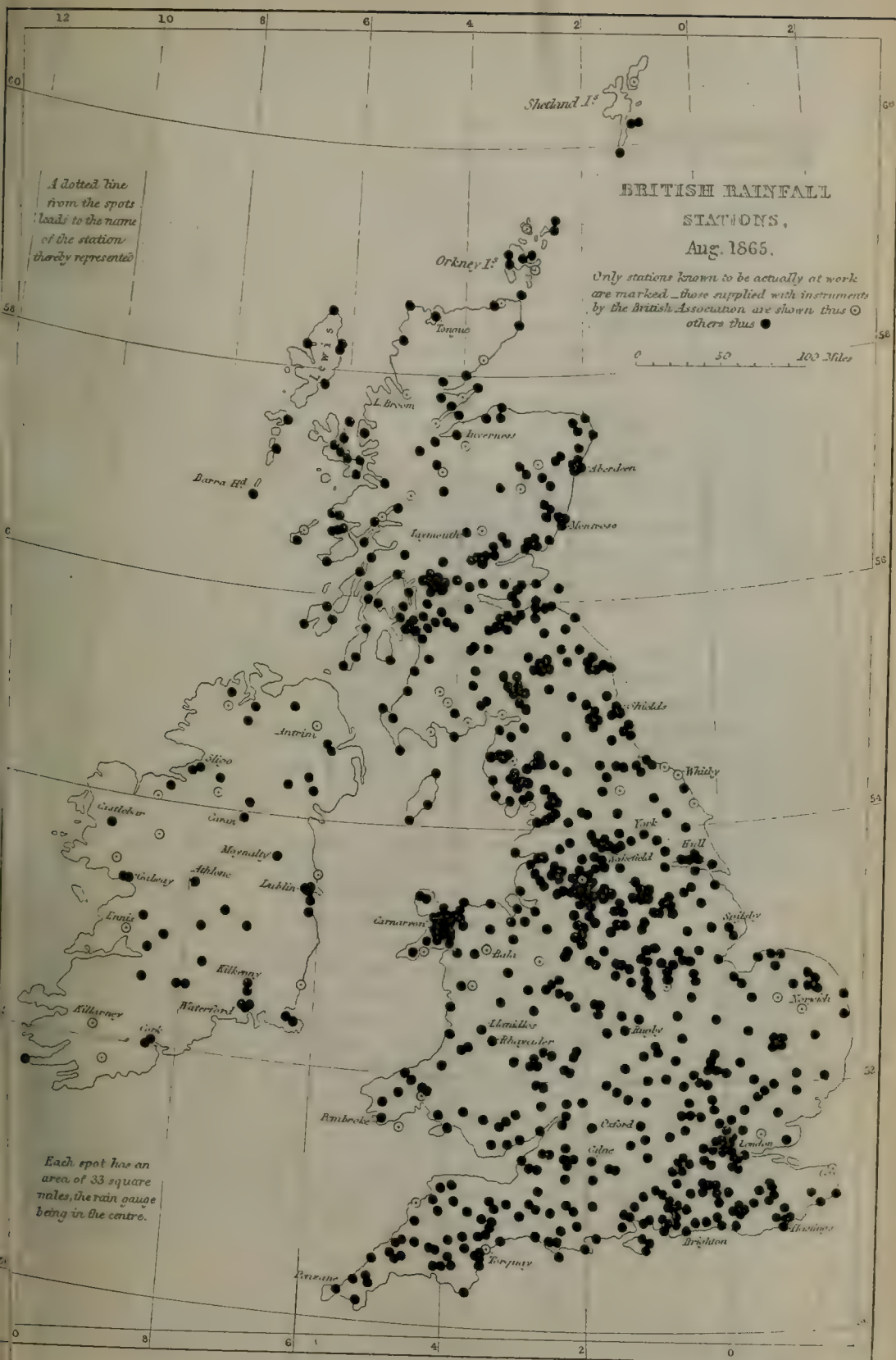
On the Rainfall of the British Isles. By G. J. SYMONS, M.B.M.S.

IN my previous reports on the progress of rainfall-investigations I have scarcely referred to what had been done before I undertook the collection and organization to which I have now devoted nearly six years.

I purpose to supply the omission on this present occasion, and to divide my Report into the following divisions:—

1. What had been done prior to 1860.
2. What has been done since 1860.
3. What remains to be done.
4. A few particulars respecting the rainfall of the last fifty years, and the fall in 1864.

1. *What had been done prior to 1860.*—Having been almost wholly engaged during the past year in clearing up arrears, and in thoroughly classifying the materials hitherto collected, the imperative necessity of circulating amongst engineers, meteorologists, and rainfall-observers a complete index of the collected observations has been brought prominently before me. I have therefore prepared such an index, and annexed it to this Report. Besides its general usefulness, it will be specially so in two respects. (1) Every station, whether discontinued or not, being entered, with the years between which observations have been obtained, and with observer's name, and height above sea-level, any one, whether engineer, agriculturist, or physicist, can ascertain with the greatest ease exactly what observations have hitherto been collected. In order to facilitate reference, the stations are arranged alphabetically in counties; and there are also provided general indexes of England and





Wales, Scotland, and Ireland. (2) Those who are willing to help on the completion of the collection will see at once what I have, and what I have not; and thereby they will be saved much needless copying and I much correspondence.

A barren index, however, throws little light on the history of rainfall-investigations. Before entering on this I desire to meet at the very outset an objection sometimes raised, viz., that we cannot trust very old observations, and therefore I may be busy collecting useless materials. I maintain that we can trust them, and have the pleasure of knowing that my friend Mr. Glaisher fully agrees with me on this point. I think them far more reliable than many modern ones; for in the 17th and early part of the 18th century, to measure the fall of rain was esteemed a serious undertaking, only to be accomplished by first-class men. The repeated reference to the height of their gauges, their diameter, and the number of pounds and ounces troy corresponding to an inch of rain over the area of the "tunnel" of their gauges, and the details frequently given, combine to render it certain that they took every reasonable precaution to secure accuracy. The results they obtained, and which *they* would hardly credit, we of the 19th century know to be just what was due to the situation of the gauges. Another point to be remembered is this:—it is not intended to use any old observations in determining the absolute mean fall at any place, or, in other words, in determining the geographical distribution of rain; that will be done from recent observations with tested instruments. The old observations will only be used for determining the existence or otherwise of secular variation, and for *that* purpose an inaccurate gauge would do as well as a perfect one.

The earliest observations I have yet obtained are those of Mr. Townley, of Townley in Lancashire, extending (with two intervals) from A.D. 1677 to 1705, or twenty-eight years. Mr. Townley believed his to be the first made in England; I do not feel sure that they were so. The only other observer in the 17th century whose observations have yet been obtained was the Rev. W. Derham, of Upminster, near Romford in Essex, who began in March 1696, and has left a series of yearly totals (months also for some years) for nineteen years.

The longest and most perfect record at present obtained was kept by Thomas Barker, Esq., of Lyndon in Rutland; it extends from 1736 to 1794, or fifty-nine years. It is doubtful if so long a record will ever again be kept by one person, with one gauge, and without interruption.

From Table I. it will readily be seen how sudden and great has been the increase of observers during the last thirty years, and especially during the last five, in which one finds the results of the recent grants of this Association. From 1677 to 1800 the returns never number more than twenty-six per annum, and averaged only four; and in subsequent ten-yearly periods the numbers average, up to 1810, 15; to 1820, 21; to 1830, 40; to 1840, 103; to 1850, 178; to 1860, 366; and at the present time the returns number rather more than a thousand. It is right to mention that no records have yet been obtained for 1687 and 1688, 1694 to 1696, 1717 to 1721, 1724 and 1725, since which time there is no year without one or more complete registers; that is to say, rain-records go back complete 140 years, and with intervals about fifty years more, or nearly 200 years altogether.

TABLE I.

Number of Records obtained for each year from 1677 to 1864.

| Year. | Number. | | | | | Year. | Number. | | | | |
|-------|-----------------------|-----------|----------|--------|---|-------|-----------------------|-----------|----------|--------|---|
| | England and
Wales. | Scotland. | Ireland. | Total. | Total in each
decennial pe-
riod. | | England and
Wales. | Scotland. | Ireland. | Total. | Total in each
decennial pe-
riod. |
| 1677. | 1 | .. | .. | 1 | 3 | 1720. | .. | .. | .. | .. | 8 |
| 1678. | 1 | .. | .. | 1 | | 1721. | .. | .. | .. | .. | |
| 1679. | 1 | .. | .. | 1 | | 1722. | 1 | .. | .. | 1 | |
| 1680. | 1 | .. | .. | 1 | 8 | 1723. | 1 | .. | .. | 1 | 36 |
| 1681. | 1 | .. | .. | 1 | | 1724. | .. | .. | .. | .. | |
| 1682. | 1 | .. | .. | 1 | | 1725. | .. | .. | .. | .. | |
| 1683. | 1 | .. | .. | 1 | | 1726. | 1 | .. | .. | 1 | |
| 1684. | 1 | .. | .. | 1 | | 1727. | 1 | .. | .. | 1 | |
| 1685. | 1 | .. | .. | 1 | | 1728. | 1 | .. | .. | 1 | |
| 1686. | 1 | .. | .. | 1 | | 1729. | 3 | .. | .. | 3 | |
| 1687. | .. | .. | .. | .. | | 1730. | 3 | .. | .. | 3 | |
| 1688. | .. | .. | .. | .. | | 1731. | 3 | 1 | .. | 4 | |
| 1689. | 1 | .. | .. | 1 | | 1732. | 4 | 1 | .. | 5 | |
| 1690. | 1 | .. | .. | 1 | 10 | 1733. | 4 | 1 | .. | 5 | 11 |
| 1691. | 1 | .. | .. | 1 | | 1734. | 5 | 1 | .. | 6 | |
| 1692. | 1 | .. | .. | 1 | | 1735. | 4 | 1 | .. | 5 | |
| 1693. | 1 | .. | .. | 1 | | 1736. | 2 | .. | .. | 2 | |
| 1694. | .. | .. | .. | .. | | 1737. | 2 | .. | .. | 2 | |
| 1695. | .. | .. | .. | .. | | 1738. | 2 | .. | .. | 2 | |
| 1696. | .. | .. | .. | .. | | 1739. | 2 | .. | .. | 2 | |
| 1697. | 2 | .. | .. | 2 | | 1740. | 1 | .. | .. | 1 | |
| 1698. | 2 | .. | .. | 2 | | 1741. | 1 | .. | .. | 1 | |
| 1699. | 2 | .. | .. | 2 | | 1742. | 1 | .. | .. | 1 | |
| 1700. | 2 | .. | .. | 2 | 14 | 1743. | 1 | .. | .. | 1 | 20 |
| 1701. | 2 | .. | .. | 2 | | 1744. | 1 | .. | .. | 1 | |
| 1702. | 2 | .. | .. | 2 | | 1745. | 1 | .. | .. | 1 | |
| 1703. | 2 | .. | .. | 2 | | 1746. | 1 | .. | .. | 1 | |
| 1704. | 1 | .. | .. | 1 | | 1747. | 1 | .. | .. | 1 | |
| 1705. | 1 | .. | .. | 1 | | 1748. | 1 | .. | .. | 1 | |
| 1706. | 1 | .. | .. | 1 | | 1749. | 2 | .. | .. | 2 | |
| 1707. | 1 | .. | .. | 1 | | 1750. | 2 | .. | .. | 2 | |
| 1708. | 1 | .. | .. | 1 | | 1751. | 2 | .. | .. | 2 | |
| 1709. | 1 | .. | .. | 1 | | 1752. | 2 | .. | .. | 2 | |
| 1710. | 1 | .. | .. | 1 | 7 | 1753. | 2 | .. | .. | 2 | 20 |
| 1711. | 1 | .. | .. | 1 | | 1754. | 2 | .. | .. | 2 | |
| 1712. | 1 | .. | .. | 1 | | 1755. | 2 | .. | .. | 2 | |
| 1713. | 1 | .. | .. | 1 | | 1756. | 2 | .. | .. | 2 | |
| 1714. | 1 | .. | .. | 1 | | 1757. | 2 | .. | .. | 2 | |
| 1715. | 1 | .. | .. | 1 | | 1758. | 2 | .. | .. | 2 | |
| 1716. | 1 | .. | .. | 1 | | 1759. | 2 | .. | .. | 2 | |
| 1717. | .. | .. | .. | .. | 7 | 1760. | 2 | .. | .. | 2 | 20 |
| 1718. | .. | .. | .. | .. | | 1761. | 2 | .. | .. | 2 | |
| 1719. | .. | .. | .. | .. | | 1762. | 3 | .. | .. | 3 | |
| | | | | | | 1763. | 1 | .. | .. | 1 | |

| Year. | Number. | | | | | Year. | Number. | | | | |
|-------|--------------------|-----------|----------|--------|---------------------------------|-------|--------------------|-----------|----------|--------|---------------------------------|
| | England and Wales. | Scotland. | Ireland. | Total. | Total in each decennial period. | | England and Wales. | Scotland. | Ireland. | Total. | Total in each decennial period. |
| 1764. | 1 | .. | .. | 1 | 39 | 1815. | 8 | 10 | 1 | 19 | 209 |
| 1765. | 2 | 1 | .. | 3 | | 1816. | 11 | 10 | .. | 21 | |
| 1766. | 5 | 1 | .. | 6 | | 1817. | 14 | 11 | 1 | 26 | |
| 1767. | 9 | 1 | .. | 10 | | 1818. | 16 | 11 | 1 | 28 | |
| 1768. | 5 | 1 | .. | 6 | | 1819. | 17 | 11 | 1 | 29 | |
| 1769. | 4 | 1 | .. | 5 | | | | | | | |
| 1770. | 2 | 1 | .. | 3 | | 1820. | 22 | 11 | 1 | 34 | |
| 1771. | 2 | 2 | .. | 4 | | 1821. | 25 | 9 | 1 | 35 | |
| 1772. | 2 | 2 | .. | 4 | | 1822. | 24 | 9 | 1 | 34 | |
| 1773. | 2 | 6 | .. | 8 | | 1823. | 24 | 9 | 2 | 35 | |
| 1774. | 4 | 6 | .. | 10 | 84 | 1824. | 27 | 10 | 2 | 39 | 401 |
| 1775. | 5 | 7 | .. | 12 | | 1825. | 28 | 12 | 1 | 41 | |
| 1776. | 5 | 7 | .. | 12 | | 1826. | 32 | 9 | 1 | 42 | |
| 1777. | 7 | 5 | .. | 12 | | 1827. | 32 | 12 | 1 | 45 | |
| 1778. | 7 | 3 | .. | 10 | | 1828. | 31 | 15 | 1 | 47 | |
| 1779. | 6 | 3 | .. | 9 | | 1829. | 32 | 16 | 1 | 49 | |
| | | | | | | | | | | | |
| 1780. | 6 | 3 | .. | 9 | | 1830. | 37 | 19 | 1 | 57 | |
| 1781. | 7 | 2 | .. | 9 | | 1831. | 46 | 25 | 1 | 72 | |
| 1782. | 8 | 2 | .. | 10 | | 1832. | 52 | 31 | 1 | 84 | |
| 1783. | 7 | 2 | .. | 9 | 133 | 1833. | 61 | 32 | 1 | 93 | 1029 |
| 1784. | 10 | 1 | .. | 11 | | 1834. | 63 | 33 | 1 | 97 | |
| 1785. | 11 | 3 | .. | 14 | | 1835. | 64 | 42 | 3 | 109 | |
| 1786. | 11 | 2 | .. | 13 | | 1836. | 71 | 49 | 3 | 123 | |
| 1787. | 14 | 2 | .. | 16 | | 1837. | 81 | 45 | 4 | 130 | |
| 1788. | 17 | 4 | .. | 21 | | 1838. | 90 | 39 | 6 | 135 | |
| 1789. | 18 | 3 | .. | 21 | | 1839. | 88 | 36 | 5 | 129 | |
| | | | | | | | | | | | |
| 1790. | 19 | 5 | .. | 24 | 176 | 1840. | 95 | 38 | 6 | 139 | 1777 |
| 1791. | 20 | 5 | 1 | 26 | | 1841. | 89 | 39 | 9 | 137 | |
| 1792. | 18 | 5 | 1 | 24 | | 1842. | 99 | 38 | 9 | 146 | |
| 1793. | 14 | 5 | 1 | 20 | | 1843. | 93 | 39 | 10 | 142 | |
| 1794. | 8 | 4 | 1 | 13 | | 1844. | 128 | 42 | 13 | 183 | |
| 1795. | 8 | 7 | 1 | 16 | | 1845. | 145 | 42 | 13 | 200 | |
| 1796. | 8 | 3 | 2 | 13 | | 1846. | 144 | 41 | 12 | 197 | |
| 1797. | 8 | 3 | 3 | 14 | | 1847. | 160 | 46 | 12 | 218 | |
| 1798. | 8 | 2 | 4 | 14 | | 1848. | 148 | 44 | 12 | 204 | |
| 1799. | 5 | 4 | 3 | 12 | | 1849. | 155 | 46 | 10 | 211 | |
| | | | | | 151 | | | | | | 3663 |
| 1800. | 5 | 3 | 2 | 10 | | 1850. | 180 | 54 | 11 | 245 | |
| 1801. | 6 | 4 | 1 | 11 | | 1851. | 212 | 53 | 13 | 278 | |
| 1802. | 5 | 4 | 1 | 10 | | 1852. | 238 | 57 | 15 | 310 | |
| 1803. | 5 | 5 | 1 | 11 | | 1853. | 237 | 71 | 14 | 322 | |
| 1804. | 5 | 6 | 1 | 12 | | 1854. | 223 | 89 | 15 | 327 | |
| 1805. | 4 | 7 | 1 | 12 | | 1855. | 266 | 107 | 16 | 389 | |
| 1806. | 5 | 5 | 1 | 11 | | 1856. | 286 | 121 | 16 | 423 | |
| 1807. | 6 | 7 | 1 | 14 | | 1857. | 297 | 130 | 13 | 440 | |
| 1808. | 20 | 9 | 1 | 30 | | 1858. | 309 | 135 | 13 | 457 | |
| 1809. | 19 | 11 | .. | 30 | | 1859. | 327 | 131 | 14 | 472 | |
| | | | | | | | | | | | |
| 1810. | 18 | 7 | .. | 25 | | 1860. | 411 | 122 | 19 | 552 | |
| 1811. | 6 | 10 | .. | 16 | | 1861. | 466 | 134 | 26 | 626 | |
| 1812. | 6 | 11 | 1 | 18 | | 1862. | 507 | 192 | 32 | 731 | |
| 1813. | 5 | 7 | 1 | 13 | | 1863. | 564 | 206 | 47 | 817 | |
| 1814. | 6 | 7 | 1 | 14 | | 1864. | 671 | 240 | 56 | 967 | |

The collection of these records has been spasmodically attempted by several persons, Dr. Dalton being among the earliest and most successful: he, in the year 1799, submitted to the Manchester Literary and Philosophical Society by far the best paper on rainfall published until many years after. Still, owing probably to the absence of postal and other means of communication, his paper by no means included all that had been done up to the time of his writing it.

The following list (Table II.) of old stations prior to 1800, is not only handy as such, but also available as a check on the completeness of Dr. Dalton's search, and of my own. The result appears to be that the Doctor, who undoubtedly took great pains with his Table, and most truly described it as "the most complete hitherto published," had not half of the records then existing, and which I and my friends have hunted up. On the other hand the Doctor has one station, "Crawshawbooth near Haslingden," of which I can get no information.

TABLE II.—Showing the Stations at which the Fall of Rain was measured previously to the year 1800.

ENGLAND.

| Counties. | Stations. | Years in hand. | Number of years. | Years quoted by Dr. Dalton. |
|-------------------------|--------------------------------------|-----------------------------------|------------------|-----------------------------|
| Cornwall | Ludgvan | 1762, 1767-71 | 6 | 5 |
| Cumberland | Carlisle | 1767 | 1 | 1 |
| " | Keswick | 1788-94 | 7 | 7 |
| Derbyshire | Chatsworth | 1777-99 | 22 | 15 |
| Devonshire | Plymouth | 1731-35 | 5 | |
| " | " | 1767 and 1768 | 2 | 2 |
| Durham | Darlington | 1734 and 1735 | 2 | |
| Essex | Upminster | 1697-1716 | 19 | ? |
| Gloucester | Bristol | 1774-78 | 4 | 3 |
| Hampshire | Andover | 1785-89 | 5 | |
| " | Fyfield | 1784-92 | 8 | 7 |
| " | Selborne | 1780-93 | 13 | 9 |
| Hertfordshire | Ware | 1787-91 | 5 | 5 |
| Kent | Chislehurst | 1729 and 1730 | 2 | |
| " | Dover | 1789-93 | 5 | 5 |
| Lancashire | Townley | 1677-86, 89-93, 97-1704 | 23 | ? |
| " | Bury | 1797-1799 | 3 | |
| " | { Crawshawbooth
near Haslingden } | None | None. | 2 |
| " | Lancaster | 1784-93 | 10 | 10 |
| " | Liverpool | 1775-92 | 17 | 18 |
| " | " Walton | 1791-99 | 9 | |
| " | " | 1784-92 | 9 | |
| " | Manchester | 1794-99 | 6 | 1 |
| " | " Holme | 1765-69 | 5 | |
| " | " Salford | 1786-93 | 8 | 8 |
| " | Fellfoot | 1788-91 | 4 | 3 |

TABLE II. ENGLAND (*continued*).

| Counties. | Stations. | Years in hand. | Number of years. | Years quoted by Dr. Dalton. |
|------------------|-------------------------|----------------|------------------|-----------------------------|
| Middlesex..... | Edmonton | 1792-96 | 5 | |
| " | Crane-ct., London | 1729-35 | 7 | 7 |
| " | Royal Society | 1787-99 | 13 | |
| " | Temple Bar | 1795-99 | 5 | |
| Norfolk | Norwich | 1749-62 | 14 | 13 |
| Northampton .. | Oundle | 1726-39 | 14 | 14 |
| Northumberland | Widdrington | 1722-23 | 2 | 1 |
| Rutland | Lyndon | 1736-94 | 59 | 21 |
| Somersetshire .. | Bridgewater | 1767-69 | 3 | 3 |
| " | Minehead | 1782 | 1 | |
| Surrey | South Lambeth.... | 1782-92 | 11 | 9 |
| Westmoreland .. | Kendal | 1788-92 | 5 | |
| " | " | 1787-99 | 13 | 11 |
| " | Benson Knott | 1790-91 | 2 | |
| " | Waith Sutton | 1789-93 | 5 | 5 |
| Yorkshire..... | Leeds, Barroby.... | 1772-81 | 10 | 6 |
| " | Garsdale | 1777-79 | 3 | 3 |

SCOTLAND.

| | | | | |
|-----------------|---------------------|-------------------------|----|--|
| Banffshire..... | Gordon Castle | 1799 | 1 | |
| Dumbarton | Kirkintillock | 1788 | 1 | |
| Dumfries | Dumfries | 1776-93 | 18 | |
| " | Langholm | 1773-77 | 5 | |
| Edinburgh | Dalkeith | 1773-77 | 5 | |
| " | Edinburgh | 1785-95 | 11 | |
| " | " | 1795-99 | 5 | |
| " | " | 1796-99 | 4 | |
| " | " | 1731-35 | 5 | |
| " | Hawkhill | 1771-76 | 6 | |
| Elgin | Urquhart | 1795-97 | 3 | |
| Forfar | Dundee | 1790-95 | 6 | |
| Lanark | Glasgow | 1765, 75, 85, 88, 95 .. | 5 | |
| Peebles | Peebles | 1766-79 | 14 | |
| Perth | Belmont Castle.... | 1789-95 | 7 | |
| Roxburgh | Branxholm | 1773-83 | 11 | |
| Selkirk | Wool | 1773-76, 80 | 5 | |

IRELAND.

| | | | | |
|----------------|--------------------|---------------|---|--|
| Antrim..... | Belfast | 1796-99 | 4 | |
| Dublin | Dublin | 1791-99 | 9 | |
| Londonderry .. | Londonderry | 1797-99 | 3 | |
| Longford | Edgworthston | 1798 | 1 | |

After Dr. Dalton's collection in 1799 there was a long interval in which, though observations were steadily continued, no one seems to have thought of collecting and discussing them. Dr. Dalton's averages were (and, I am sorry

to say, are still sometimes) constantly quoted, and no notice was taken of subsequent observations. This is the more to be regretted since some of the gauges quoted by Dr. Dalton were on roofs, others on the ground, and no distinction was made between them.

I am not at present aware of any extensive collection between 1799 and 1840, or thereabouts, when Mr. Joseph Atkinson, of Harraby near Carlisle, published a rain-map of the British Isles: to my great vexation I cannot obtain a copy; and there is not one in the British Museum. It only gives the mean fall, and contains only two or three places besides those I possess; but it is provoking that a copy of so recent a publication (1841 or 1842) cannot be obtained. During the last ten or twenty years several collections have been made, those of Mr. Glaisher for the British, and Dr. Stark for the Scottish, Meteorological Society having been published, with other meteorological details, quarterly by the Registrars-General of the respective countries. The prize offered by the Marquis of Tweeddale for an essay on rainfall, and awarded to Mr. Jamieson, of Ellon, led to the collection of the yearly fall at about twenty British stations, and the collection in Mr. Beardmore's splendid 'Manual of Hydrology' completes the list of my precursors. The two last have been published since 1860, but it seems appropriate to notice them here: the most copious of these Tables, however, did not contain a tenth of the extensive observations.

It is a singular fact, that, with the exception of the last two works, no notice has ever been taken of the position of the gauges, on which so much depends that a West-country roof record will often be less than an Eastern-counties ground-record; that is to say, the difference due to elevation is often greater by far than that due to a hundred miles geographical distance. Paramount as is the importance of distinct information on this point, it is never referred to in any of the old or many modern Tables.

This omission naturally leads me to refer to the variation in the amount collected according to the height at which the gauge is placed above the surface of the ground. This was first noticed in 1765; and in 1766 Dr. Heberden, F.R.S., placed a gauge on the square tower of Westminster Abbey, another on the roof of an adjacent house, and a third in a garden, and found the fall to be, —garden, 22·61; roof, 18·14; abbey-tower, 12·10. These experiments were promptly repeated at "Bath, Liverpool, Middlewich, and elsewhere;" but I have not been able to find any notice beyond the simple fact that "the results were similar to those at Westminster." (This shows how much is either still buried, or lost altogether.) Shortly after this, the Hon. Daines Barrington erected two gauges in the vicinity of Bala, in North Wales—one at Rennig, and one on the summit of Bochyraidr (1700 feet?)—and ascertained therefrom that the decrease did not depend on actual elevation, but on the height above the surface of the ground. This subject, I need hardly remind members of this Association, was carefully investigated by our esteemed President, Professor Phillips, when living at York in 1832; in fact it was one of the first subjects this Association took in hand.

The heavy fall of rain in mountainous districts was noticed at a very early period; but very little was done, until a comparatively recent date, towards systematic observation and the determination of the laws governing the distribution of rain in mountainous districts. Mr. Bateman's observations in the Derbyshire and Yorkshire hills, followed as they were by the elaborate investigations carried on by the late Dr. Miller in the Lake-district, have left for future examination only the subsidiary and minor variations to which the laws they deduced are liable.

2. *What has been done since 1860.*—Having thus described what had been done previously to 1860, I proceed to mention briefly what has been done since then; and if it seems that this portion is egotistical, I reply I cannot help it: it would be strange indeed if the one person who has devoted himself solely to the subject were not mixed up with most of its ramifications.

In the first place, then, it has already been stated that prior to 1860 there had been no general collection of all reliable rainfall-records; this was the primary object I had in view, knowing that without such a collection it was impossible to determine, with any approach to accuracy, either the geographical distribution or secular variation of British rainfall. To what an enormous magnitude this collection has grown may be inferred from the Tables attached to this Report; but as a ready means of enabling engineers and others to estimate the stores awaiting them, I may say that, supposing the lists closed at once, I believe the publication of the monthly values and discussion of the observations would fill two of the bulky annual volumes of this Association. Of course bulk is a poor test of value; but I wished to give some better description than that of “twenty-three folio volumes of MS.,” which are already full. I should not omit to state whence these observations have been copied. Most of them have been obtained from the observers, many of whom have sent me registers of ten, twenty, thirty, and even more years in length; some are from privately printed papers, others from magazines, scientific journals, and Transactions of the Royal and other Societies. Particulars as to the position of the gauge are always carefully noted along with the observations, *when* they can be obtained. I had not been at this work very long before I felt the desirability of publishing *some* information of a reliable character, and at the close of 1860 I published a Table giving the total depth in that year at 168 stations, being more than double the number ever previously collected; this Table has grown into an annual volume, both by giving additional information on the undermentioned and other subsidiary investigations, and by its increased body of contributors, now numbering over 1000.

Next to compiling the general Tables and annual reports, the most troublesome, but probably also the most important, work is the examination of the gauges actually in use, both as to their own accuracy and also as to the suitability of their position. I need not point out how necessary this is; it must be evident to everybody that until it is done there will be liability to all sorts of errors in deducing results from observations with gauges either themselves incorrect, or badly placed. I do not wish to be discursive; or I could quote many positions in which I have found gauges, nothing less than absurd. (Very gross errors are *now* impossible, owing to the number of new tested gauges interspersed among the old ones and available as checks upon them.) This examination of the gauges *in situ* involves an amount of travelling which takes far too much time and too much money for me to make any very great progress with it. However, I have visited 113; and if this Association will find the needful funds, I will endeavour to double the number before I draw up the next annual Report.

Next to personally visiting each gauge, the best plan is to test the gauges before the opticians send them off to their destinations. Of the exact number thus tested I have no record, but believe it to be about 300, a number easily mentioned, but by no means so easily examined.

At the outset of the investigation an attempt was made to collect returns of the number of rainy days or days of rain; but it was speedily found that utter want of uniformity prevailed, and that it was useless to attempt to do

anything with them. After consulting the observers, each of whom was asked to send in his or her definition of a rainy day, the plan I recommended was to count as a day of rain every one on which 0·01 inch fell. How this will work remains to be seen; but it is certainly a step in the right direction—that is to say, towards uniformity.

Another point noticed at an early period was the unequal geographical distribution of the stations, some parts of the country being amply provided, while in others the gauges were fifty or sixty miles apart. Thanks to the £55 granted by this Association, this state of things no longer exists; how it has been removed may be learnt from my previous Reports, or from the accompanying Map. Of course there are still great inequalities, but they are as nothing compared with what existed in 1859.

It remains to notice the series of experimental gauges which have been recently started to settle various disputed points. Reference has already been made to the decreased amount of rain caught in gauges placed on high buildings, and to the experiments of Dr. Heberden and Professor Phillips on the subject. On finding that (owing to the previous absence of any rainfall centre, if I may so term myself) the gauges throughout the kingdom were at all sorts of elevations, from 90 feet downwards, it was evident that some means must be devised for correcting these observations and reducing them to what they would be if made at one uniform level. Many of the gauges being elevated on pillars or pedestals, it was urged, and with apparent reason, that as all previous elevation experiments had been made upon, and in the vicinity of, buildings, the laws of decrease deduced therefrom were not, or at any rate might not, be applicable to gauges mounted as above described. In order to test this point, Colonel Ward, of Calne, kindly undertook the cost and trouble of mounting a set of gauges on part of his lawn, a description of which I read to this Section at the Newcastle Meeting; they are now eleven in number, and at heights varying from level with the ground to 20 feet above it. In order to check the applicability of the Calne results to other localities, a similar but less extensive set of gauges has been established near Manchester by the Rev. J. Chadwick Bates.

It was rather singular that, although, as before stated, rainfall has been measured in this country nearly two hundred years, there had been prior to 1860 no published experiments on a comprehensive scale to determine the best size and form of gauge. It would be inappropriate here to enlarge to any extent upon the various theories put forth upon the subject; and I will only remark that the gauges principally issued by the Scottish Meteorological Society are but 2 or 3 inches in diameter, while a high Scottish authority “has no faith” in anything less than a foot in diameter. Mr. Glaisher’s gauges, everybody knows, are 8 inches in diameter, Luke Howard’s 5 inches, and the Royal Engineers’ are 1 foot square. An exhaustive set of experiments have therefore been undertaken on this point also, by Col. Ward and Mr. Bates, the gauges varying from 1 inch to 2 feet in diameter—square gauges, turf-gauges, snow-gauges, &c., being also tried. Col. Ward has altogether 29 gauges at work; and Mr. Bates has, I believe, 13, beside the thermo-rain-gauge mentioned below.

Reference was made in the earlier part of this Report to the peculiarly heavy rainfall in mountainous districts, which had been carefully observed in Cumberland during the years 1844 to 1853. It was felt that it would be very interesting to ascertain if similar physical configuration received similar fall in other parts of the country, and that the district round Snowdon appeared very suitable for the experiments. Favoured by the assistance of my friend Mr. Rogers Field, of Hampstead, and that of Captain Mathew, of Wern,

Carnarvon (who really did most of the work), we now have returns from more than thirty tested gauges in that district, at elevations varying from 15 feet to 1100 feet. Simultaneously with the establishment of these, the Cumberland gauges have been reestablished by Mr. Isaac Fletcher, F.R.S.; so that we now have for the first time full records from both districts. At present the Welsh records are far below the Cumberland ones; whether this is due to the fact that *the* wet places in Snowdonia have yet to be found, or whether the deficiency is due to the Cumberland gauges lying near the track of the centres of British cyclones, or to some other cause, has yet to be determined.

3. *What remains to be done.*—On this point it is not so easy to speak clearly and decisively as on the preceding ones, because every one knows that just as an investigation progresses so do new branches claim attention. Some of the leading items may, however, be easily specified. In the first place, the collection of old observations must be rendered as complete as possible, by diligent search at the British Museum, in the libraries of the various scientific societies, and elsewhere. As an illustration of the meaning of that simple word “elsewhere,” I may mention that on the day I was writing this Report I received a note from the Secretary to the Board of Northern Lights, respecting the rain-records kept at their lighthouses, with copies of the *current* returns of which I have been favoured during the past three years. From this note I find that the returns have been kept ever since 1813, but that they have never been tabulated or discussed. As far as I can at present tell, there seems to be about fifty years’ records of twenty-five stations (=1250 yearly records) to copy out. This I have ordered to be done; but of course the expense will fall upon me. This however, is, only quoted as a specimen of the work to be done in *collecting*. After it, will come the discussion, which will also occupy a considerable time. The current returns for each year have of course to be examined and prepared for publication at its close (this takes two persons six weeks). About 900 gauges remain to be visited; and this involves perhaps 10,000 miles’ travelling, much of which must be on foot, and all of which involves a heavy expenditure of time and money. I need not dwell on the testing of new gauges, since the time so occupied is comparatively trivial. A more serious item will be the analysis and discussion of the experimental-gauge records of Col. Ward and Mr. Bates, and the mountain gauges of Mr. Fletcher and Capt. Mathew. I have been already much helped by volunteer labour; perhaps some careful person, who does not mind voluminous work, will relieve me of one or other of these discussions.

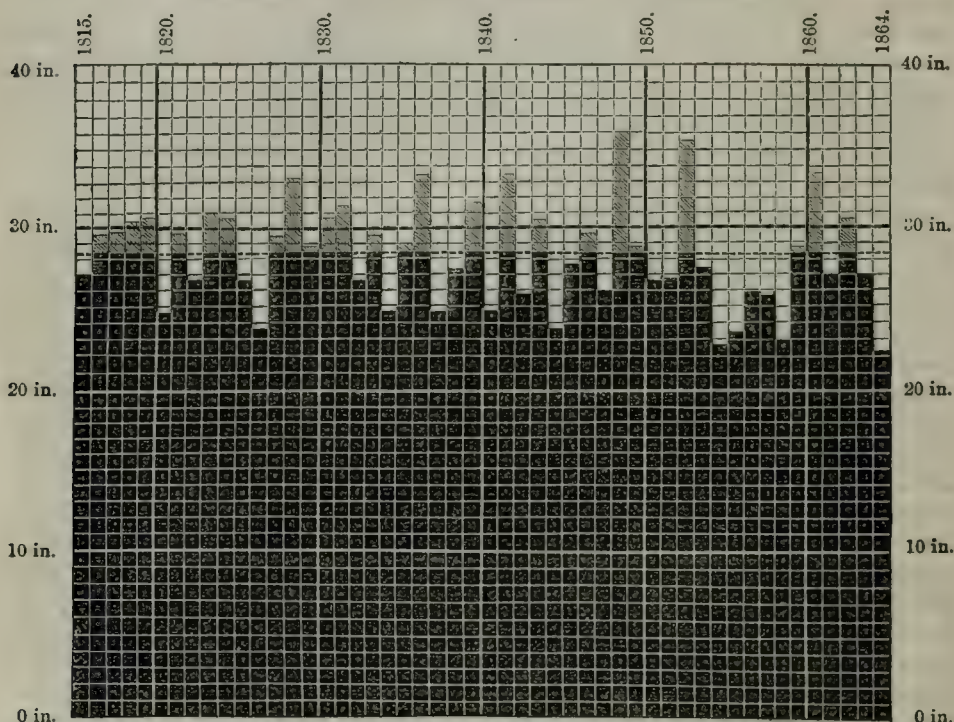
In drawing this section of my report to a close, I may just mention a few other matters I have in hand:—The construction of a cheap and accurate gauge for ordinary use: the one here shown is the last improvement and most compact I have seen; and the maker, Mr. Apps, of 433, Strand, undertakes to supply them at 10s. 6d. each; so I hope no one will say they use a home-made gauge because the opticians charge so much. Mr. Apps is also making a self-recording gauge, to show the exact duration and intensity of each shower. The Rev. J. Chadwick Bates has at Castleton Moor started a thermo-rain-gauge for ascertaining the temperature of falling rain, on which the variation according to elevation is supposed to depend. Then I have on hand some experiments suggested by Mr. Smith, of Jersey, for measuring, by nitrate of silver, the percentage of sea spray mingled with rain-water at West-country stations.

I close this programme of work to be done, trusting that I have shown that far more remains to be done than I have yet accomplished, and that, if I am only efficiently supported, important points may be cleared up. Into

financial matters I believe I must not enter; but there can be no harm in stating that by what has been done I have lost over £300, and a lucrative post; and inasmuch as it is impossible for me to continue under such conditions, the "work to be done" will not become "work done" unless I am protected from further loss. The Royal Society have recently granted £50 towards the general expenses of the investigations; the observers naturally think that by observing they do their share, at the same time they have subscribed about £150; but the total of £200 by no means meets the outlay of so extensive a work as mine.

4. *A few particulars respecting the rainfall of the last fifty years, and the fall in 1864.*—And first with reference to the fall during the past half century, to an examination of which I gave some little attention during the last spring. The accompanying diagram* best explains the result of this

Rainfall 1815 to 1864—Mean of Ten Stations.



temporary investigation. I wish to emphasize that word temporary very strongly, because one can never be sure that a partial investigation, based on a few records, yields the same result as if all were combined, as I hope eventually to have them, when, instead of discussing the variation in half a century, we may hope to discuss the records of two centuries.

So much interest is now taken, both in and out of Parliament, in questions of drainage, water-supply, and the condition of our rivers, and I am so constantly urged to give some information on the point, that I rather feel as if I was acting the part of the dog in the manger, in gathering volume after volume of rainfall-observations and yet deducing no results. My objection has been, that though much has been collected, as much (or more) remains to be done, and I have a great horror of incomplete work; but not having hitherto had the least assistance, and seeing no prospect of getting any except

* It is almost superfluous to state that the total fall in each year is shown by the top of the column, whether black or shaded, the difference being only made to show prominently the years *above* and *below* the dotted average line.

by paying clerks' salaries out of my own pocket, it will be some years before the inquiry can be completed. Under these circumstances, it seemed unreasonable to persist in my refusal of an interim investigation, and I have therefore drawn up the following statement.

My object has been to determine (1) whether the decreased annual fall of rain which has been observed at Greenwich is a local variation, or whether it prevails generally throughout the country; (2) (having ascertained that the present, temporary investigation shows it to be general) to ascertain in what districts the decrease is most marked.

Unfortunately there are very few continuous records extending back more than about thirty years. A few, however, are available and, having carefully interpolated for one or two missing years, I have been able to form the following Table from the mean of ten widely separated stations—one in each of the following counties: Devon, Kent, Middlesex, Surrey, Essex, Lincoln, Lancashire, York, Edinburgh, and Argyll.

It may be well to add that on carrying the examination back to 1800, the fall seems to have been *less* than it was about 1815, when the following more reliable Table commences.

Mean depth of Rain at ten stations, 1815–1864.

| Year. | Depth. | Year. | Depth. | Year. | Depth. | Year. | Depth. | Year. | Depth. |
|-------|--------|-------|--------|-------|--------|-------|--------|-------|--------|
| 1815 | 27·12 | 1825 | 26·57 | 1835 | 28·56 | 1845 | 27·87 | 1855 | 23·37 |
| 1816 | 29·26 | 1826 | 23·76 | 1836 | 33·49 | 1846 | 29·57 | 1856 | 25·89 |
| 1817 | 29·73 | 1827 | 29·53 | 1837 | 24·54 | 1847 | 25·80 | 1857 | 25·70 |
| 1818 | 30·34 | 1828 | 33·02 | 1838 | 27·11 | 1848 | 35·98 | 1858 | 22·79 |
| 1819 | 30·46 | 1829 | 28·70 | 1839 | 31·27 | 1849 | 28·51 | 1859 | 28·53 |
| 1820 | 24·53 | 1830 | 30·83 | 1840 | 24·67 | 1850 | 26·35 | 1860 | 33·34 |
| 1821 | 29·92 | 1831 | 32·28 | 1841 | 33·51 | 1851 | 26·70 | 1861 | 26·98 |
| 1822 | 26·63 | 1832 | 26·20 | 1842 | 25·53 | 1852 | 35·53 | 1862 | 30·37 |
| 1823 | 31·09 | 1833 | 29·71 | 1843 | 30·40 | 1853 | 27·38 | 1863 | 26·93 |
| 1824 | 30·91 | 1834 | 24·52 | 1844 | 23·72 | 1854 | 22·38 | 1864 | 22·11 |
| Mean | 28·999 | Mean | 28·512 | Mean | 28·280 | Mean | 28·607 | Mean | 26·601 |

Several curious results may be noticed in this Table: for instance, in the first ten years, seven were above the average of fifty years; in the next ten, six; in the next, five; in the next, four; in the last, three. Again, out of the first twenty-five years, sixteen were *above* the average; and in the next, sixteen were below it.

Means from the above values.

| Five-year Means. | | | Ten-year Means. | | |
|------------------|-------|-------------|-----------------|-------|-------------|
| Years. | Mean. | Difference. | Years. | Mean. | Difference. |
| 1815–1819 | 29·38 | + 1·18 | 1815–1824 | 29·00 | + ·80 |
| 1820–1824 | 28·62 | + ·42 | 1825–1834 | 28·51 | + ·31 |
| 1825–1829 | 28·32 | + ·12 | 1835–1844 | 28·28 | + ·08 |
| 1830–1834 | 28·71 | + ·51 | 1845–1854 | 28·61 | + ·41 |
| 1835–1839 | 28·99 | + ·79 | 1855–1864 | 26·60 | –1·60 |
| 1840–1844 | 27·57 | – ·63 | | | |
| 1845–1849 | 29·55 | + 1·35 | 1820–1829 | 28·46 | + ·26 |
| 1850–1854 | 27·67 | – ·53 | 1830–1839 | 28·85 | + ·65 |
| 1855–1859 | 25·26 | – 2·94 | 1840–1849 | 28·56 | + ·36 |
| 1860–1864 | 27·95 | – ·25 | 1850–1859 | 26·47 | – 1·73 |

Mean of 25 years, 1815–1839 = 28·80.

” 50 ” 1840–1864 = 27·60.

” 50 ” 1815–1864 = 28·20.

From these Tables we find that when, as in this case, local irregularities are neutralized by the combination of observations from a large tract of country, rainfall-records evince a regularity not before expected, the main and marked feature being the drought in the years 1854 to 1858; *omit* these five years, and the records run in five-year means without a single departure of an inch from the average. But it will not do thus to *omit* them; they were exceptional, but are part and parcel of the whole, and must by no means be separated, but the whole carefully examined. For several reasons it seems better to take the ten-year means; and from them we find that the annual fall in each ten years from 1815 to 1854 was nearly equal, and always greater than in the last ten years, 1855 to 1864, and, moreover, that the ten years 1845 to 1854 had a rainfall (28·61) nearly identical with the mean (28·60) of the preceding thirty years, 1815 to 1844. Hence it is evident that at any stations where observations have been made continuously from 1845 to 1864, we may take the ten years 1845 to 1854 as representing the forty years, 1815 to 1854, and the difference between the first and last ten years as representing approximately the decrease of rainfall at that place.

The results of this investigation are condensed in a Table, and laid down on a map* (not printed), which shows the percentage by which the rainfall in the last ten years fell short of the mean of the previous ten (=40) years, the numbers being enclosed by a ring in those few cases where the fall in the last ten *exceeded* the previous ten. It will, I trust, be evident to all, that though there are some stations which yield discordant results, yet the general harmony is quite equal to what could be expected of a preliminary investigation. Still the results are only those of a partial examination of the question, and of course may be proved fallacious by observations subsequently received. The leading features at present seem to be (1) a decrease averaging 4 per cent. over the whole British Isles, but unequally distributed, the decrease being exchanged for an increase in parts of Ireland and the south of Scotland. (2) In England, although the amount of decrease varies up to 18 per cent., it never falls below an excess (if the expression may be allowed) of 2 per cent. (3) Although at first the figures seemed very discordant, yet on drawing the lines shown on the map referred to, some order seems to become evident, viz. that the maximum deficiency has existed along a line running nearly S.W.—N.E. from Cornwall to the Wash. Proceeding north-westward, the deficiency becomes less, until the parallel line running through the centre of Ireland, and passing into the North Sea at Edinburgh, marks a district in which no deficiency has existed, but, on the contrary, an excess of nearly 10 per cent. The next districts follow nearer to each other, and seem to involve the eventual adoption of W.—E. instead of S.W.—N.E.: possibly this is not really the case, but due to errors of observation at the lighthouses, whence most of the values herein assigned for Scotland are derived; or it may arise from the modifying influence of Ireland not being felt in those higher latitudes. I might further point out that the deficiency seems in some degree connected with the large drainage operations in the midland and eastern counties of England; but until, either by my own efforts, or the assistance of this Association, the observations are rendered more complete, it is not safe to attempt to determine the causes of the recent fluctuations.

The next point (and one on which I reserve full particulars for the next Report, so that 1864 and 1865 may be considered together) is the rainfall of 1864, which, as everybody knows, was far below the average in most parts of England; and in the eastern counties scarcely half the usual quantity of rain

* The map can be seen at Mr. Symons's residence, 136 Camden Road, N.W.

fell; in Cornwall also, and in Devon, where ordinarily water in abundance runs to waste, great inconvenience and loss arose from its deficiency. The most singular case was that of the Pentland Hills and the south-east of Scotland generally, where the drought was equally severe, but in less than a week the rivers rose from almost the lowest point previously known, to a higher level than had been known for eighteen years. The Edinburgh Water-works reservoirs had been so empty that the city was put on short supply; the floods of October 22-24 came and almost filled them; the rivers rose, and carried away farm-produce, buildings and bridges; and the rain-returns for that district eventually show a yearly total nearly as much above the average as our English returns are below it.

Explanation of Arrangement and Symbols used in the following List.

The stations are classed primarily into countries, secondarily into counties (which are in alphabetical order); and in each county the stations are arranged alphabetically under their own name, if a well-known one, as "Wantage;" if the place is not one generally known, they are placed under that of the nearest well-known name: for example, "Tiverton (Hayne)," Hayne being the absolute place of observation, and being near to Tiverton. When a station is on the edge of a county, and the most prominent adjacent town is in the next county, the station is classed under its own name, and that of the town is in brackets: thus, "Stotfold [Baldock]." The column headed "Elevation" states the height of the gauge above mean sea-level. An asterisk (*) prefixed to a station shows that the gauge was tested by Mr. Symons before it was used; a dagger (†), that it has been visited, tested, and its position examined. The letters B.A. indicate its having been supplied out of the grants made by the British Association. The column headed "Observer" is added principally as a means of identifying the returns when there are two or more in the same place. The column headed "Period" states the years of which the monthly fall has been collected; the letters C and T denote respectively the commencement and termination of the register; in all other cases there may be, or are, additional years constantly accruing. A bar between the date thus, 1846-52, shows that every year from 1846 to 1852 is in hand; a bar at the end thus, 1851-, shows that every year from 1851 to the present is in hand, and that the register is still kept up. When no date is given, no observations have been obtained. When a date is given in parenthesis (1840-8), it indicates the date during which I believe it to have been at work.

ENGLAND.

BEDFORDSHIRE.

| | Station. | Elevation. | Observer. | Period. |
|---|------------------------------|------------|----------------------|---------------|
| † | Amphill | ... | W. S. Slinn, Esq.... | C 1865- |
| | Bedford (Britannia Farm) ... | ... | Mr. T. Bowick | C 1865- |
| | „ (Harpur Street)..... | 112 | Dr. Barker | C 1851- |
| | „ (Observatory)..... | ... | Admiral Smyth..... | 1831, 1833-38 |
| | „ (Cardington Staff gauge) | 100 | Mr. M'Laren | C 1846- |
| | „ (Obs. gauge)..... | 100 | „ | C 1848- |
| | „ (36 ft. + ground) | 136 | „ | C 1848- |
| | „ (Sharnbrook) | ... | R. S. Stedman, Esq. | |
| | Potton (Sutton Park) | ... | Sir J. M. Burgoyne. | C 1864- |
| | Stotfold [Baldock] | 220 | W. Denne, Esq. ... | 1864- |
| | Woburn (Aspley)..... | 460 | Rev. G. W. Mahon.. | C 1856- |

BERKSHIRE.

| | Station. | Elevation. | Observer. | Period. |
|---|------------------------------|------------|------------------------|---------------------|
| | Abingdon (Kington Bagpuze) | ... | A. Murdoch, Esq. . | 1845 |
| | " (Long Wittenham) | 170 | Rev. J. C. Clutterbuck | C 1851- |
| | Hungerford | 320 | Rev. T. E. Blackwell | 1838-44, 1846-49 |
| | Maidenhead (White Waltham) | ... | J. Silver, Esq. | 1859-60. |
| | Newbury | ... | | 1845 imp. |
| | " (Greenham) | ... | J. Ward, Esq. | C 1865- |
| | Reading (Aldworth) | 500? | Rev. J. T. Austen ... | C 1838-41, 1843-48T |
| | " (Mortimer Lodge) . | ... | | (1832-9). |
| | Sandhurst | 246 | Dr. Collins | C 1817- imp. |
| | Wallingford (The Castle) ... | 175 | J. K. Hedges, Esq. | C 1863- |
| | " (Moulsford) ... | 200 | Mr. J. B. Spearing | C 1861-63 T |
| | " (Streatley) | 100 | Rev. J. Slatter | C 1862. |
| * | Wantage | ... | E. C. Davey, Esq. | C 1865- |
| | Windsor (Cumberland Lodge) | 200 | Major-Gen. Hood | C 1862- |
| | " (Parkside) | ... | W. Menzies, Esq.... | 1862- |

BUCKINGHAMSHIRE.

| | | | | |
|--|-------------------------------|-----|-----------------------|--------------------|
| | Amersham (Latimer) | ... | Dr. King | 1848-50 |
| | Aylesbury | ... | T. Dell, Esq. | 1838-39, 1841 |
| | " (County Asylum) | ... | Dr. Miller. | |
| | Fenny Stratford (Linslade)... | ... | Mr. J. Osborne. | |
| | Hartwell House | 250 | Dr. Lee | 1860-62 |
| | " Rectory | 290 | Rev. C. Lowndes ... | 1860-63 |
| | High Wycombe | ... | J. G. Tatem, Esq.... | 1829, 33, 1836-40 |
| | " | ... | S. L. Kent, Esq. ... | C 1823-37, 1839-42 |
| | Newport Pagnel | ... | R. Littleboy, Esq.... | C 1864- |
| | Slough (Chalfont) | ... | | (1860) |
| | Wendover | ... | Rev. T. Skeen | 1838-39, 1841 |

CAMBRIDGESHIRE.

| | | | | |
|---|-----------------------------|-----|-----------------------|--------------------|
| | Abington Pigotts | 130 | G. Pigott, Esq. | C 1863- |
| † | Cambridge (Beech House) ... | 46 | J. Nutter, Esq. | C 1862- |
| † | " (Christ College) | ... | Rev. J. Hays. | |
| | " (Observatory) ... | 88 | Prof. Adams | 1860-63 imp. |
| * | " (" new gauge) | 88 | " | C 1864- |
| | Deeping Fen | ... | | |
| | Fulbourne | ... | Rev. J. H. Usill ... | C 1861- |
| | Outwell Sluice | 16? | R. Lunn, Esq. | 1852-56, 1858- |
| | Ely (Stretham) | ... | Mr. Stanley | 1864- |
| | Swaffham Bulbeck | ... | Rev. L. Jenyns | 1842-3, 1845, 1849 |
| | Wisbech (North Brink) | 11 | A. Peckover, Esq.... | C 1859- |
| | " (Observatory) | 8 | S. L. Miller, Esq.... | C 1861- |
| | " (" 8 ft.) | 18 | " | C 1863- |
| | " (" 35 ft.) | 45 | " | C 1862- |
| | " (St. Mary's) | 10 | H. J. Little, Esq.... | C 1863 |

CHESHIRE.

| | | | | |
|--|-----------------------------|------|----------------------------------|----------|
| | Altringham (Bowden) | ... | A. Nield, Esq. | |
| | Birkenhead (Woodside) | ... | W. Armistead, Esq. | 1838 |
| | Frodsham (Kingsley) | 193 | Rev. R. Tyas | C 1861- |
| | Handford (Quarry Bank) ... | 295 | J. Henshall, Esq. ... | C 1860- |
| | Hyde | ... | Mr. Ashton | 1831-40. |
| | " (Kingston Mills) | 350 | H. H. Clayton, Esq. | C 1863- |
| | Knutsford (Alderley) | ... | Rev. E. Stanley | 1815-24. |
| | Macclesfield | 539 | M. S. & L. R. ¹ | C 1855- |
| | " (Park Green) ... | 500 | W. Jefferey, Esq. ... | C 1850- |
| | " (Bollington) | 1279 | M. S. & L. R. | 1850- |
| | " (Bosley Minns) | 1210 | " | 1850- |

¹ M. S. & L. R. denotes gauges kept for the Canal Department of the Manchester, Sheffield and Lincolnshire Railway Company.

CHESHIRE (*continued*).

| Station. | Elevation. | Observer. | Period. |
|-------------------------------|------------|----------------------|-------------------|
| Macclesfield(BosleyReservoir) | 590 | M. S. & L. R..... | 1850-52, 1855- |
| Marple (Aqueduct) | 321 | " | 1851- |
| " (Top Lock) | 543 | " | 1840, 1844-7, 59- |
| " " Soc. gauge | ... | Manchester Memoirs | 1844-47 |
| Mottram (Hill End) | 680 | M. S. & L. R. | C 1860- |
| " (Matley's Field) ... | 399 | " | 1851-5 imp., 1857 |
| Nantwich (Wrenbury)..... | ... | Mr. Hardacre. | |
| Newton | 396 | M. S. & L. R. | 1851- |
| Northwich | 42 | E. L. Williams, Esq. | C 1863- |
| Parkgate (Willaston) | ... | — Waring, Esq. ... | C 1861- |
| Runcorn (Weston Point) ... | 15 | E. L. Williams, Esq. | C 1863- |
| Staleybridge (Arnfield) | 575 | J. F. Bateman, Esq. | 1855- |
| " (Sandy Vale) ... | 320 | | 1844- |
| " (Godley) | 500 | J. F. Bateman. | 1854- |
| Tarporley (Alraham Green). | ... | A. Winkfield, Esq. . | C 1864- |
| Thelwall [Warrington] | 96 | J. Atkinson, Esq.... | 1861-63 T |
| Whaley | 602 | M. S. & L. R. | 1850- |
| Woodhead ¹ | 680 | J. F. Bateman, Esq. | 1855- |
| " (Brinks Edge). . | 1500 | Manchester Memoirs | 1847 |
| " (Brushes)..... | 480 | " | 1845-51 |
| " (Butterley Moss) | 1750 | " | 1846-48, 1850-51 |
| " (Crowden Hall). .. | 700 | " | 1846-51 |
| " (Rakes Moss) ... | 1620 | " | 1846-47 |
| " (Windyate Edge) .. | 1700 | " | 1845-51 |

CORNWALL.

| | | | |
|-------------------------------|-----|-------------------------------|-------------------|
| Bodmin..... | 325 | Capt. Liddell, R.N. | 1850- |
| " (65 ft.)..... | 390 | " | C 1865- |
| " (Pencarrow) | 230 | Mr. Jones | 1841, 42, 45, 60- |
| " (Warleggan) | 800 | Rev. D. Clements... | 1860- |
| Callington (Pentillie) | ... | Rep. R. Corn. Pol. S. | 1842-43 |
| " " | ... | A. Coryton, Esq. | |
| Camelford..... | 580 | Miss Pearse | 1862- |
| " (Lanteglos)..... | 460 | Rev. J. Wilkinson . | 1863- |
| Falmouth | 120 | L. Squire, Esq. | C 1835-57 T |
| * " (Wood Lane)..... | ... | H. M. Harvey, Esq. . | C 1865- |
| Helstone | 115 | M. P. Moyle, Esq. . | C 1841- |
| Launceston (Altarnum) | 570 | C. U. Tripp, Esq.... | C 1864- |
| " (Landue)..... | ... | Gardeners' Chronicle | 1850-53 |
| Liskeard | ... | | 1855 imp. |
| " | ... | S. Jenkin, Esq..... | 1864- |
| " (Boconnoc) | ... | | 1855 imp. |
| Padstow (S. Petroc Minor)... | 96 | Rev. Sir H. Molesworth, Bart. | 1855-61 T |
| " (S. Minver)..... | ... | | (1859) |
| Penzance | 50? | Mr. Giddy | 1821-28 |
| " | 94 | W. H. Richards, Esq. | C 1859- |
| " | ... | | 1833 |
| " | ... | Mr. Henwood | 1855-57 |
| " (Ludgvan) | ... | Rev. W. Borlasse ... | 1762, 1767-71 |
| Port Isaac (Roscarrock) | 210 | M. Guy, Esq. | C 1856- |
| Redruth (Tehidy)..... | 100 | Mr. Beddard | 1859- |
| St. Agnes | 300 | Dr. Barham | C 1863- |
| * St. Austell (Trevarna)..... | ... | W. Coode, Esq. ... | C 1865- |
| St. Columb (New Quay)..... | 80? | Dr. Barham | 1848-53, 1855 |
| " " | ... | | 1855 |
| " " | 90 | Mr. Tregidgo | 1862- |

¹ See also Derbyshire.

CORNWALL (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---|------------------------------|------------|-------------------------------|--------------|
| | St. Germans (Port Eliot) ... | ... | Mr. Lynch. | |
| | " (Tideford) | 50 | Rev. T. Hullah..... | C 1861-64 T |
| | Scilly (St. Mary's) | 30 | J. G. Moyle, Esq.... | C 1855-62. |
| | Scilly | ... | | 1841-43 imp. |
| | Stratton. | | | |
| * | " (Kilkhampston) ... | 475 | Rev. A. Thynne ... | C 1864- |
| | Truro (Alverton) | 65 | | 1852-53 |
| | " (Penarth) | 190 | N. Whitley, Esq. ... | C 1857- |
| | " (Royal Institution) ... | 56 | Dr. Barham | C 1838- |
| | Wadebridge (St. Breocke) ... | ... | Rev. Sir H. Molesworth, Bart. | 1837-50 |
| | " (Treharrock Ho.) | 303 | F. B. Hambly, Esq. | C 1853- |

CUMBERLAND.

South Mountain Districts ¹.

| | | | | |
|---|------------------------|------|--------------------------------|------------------|
| | Brant Rigg | 695 | I. Fletcher, Esq. ... | C 1864- |
| | " | 924 | Dr. Miller..... | 1846-53 T |
| | Crummock Lake | 260 | " | 1845-53 T |
| | Ennerdale Lake | 246 | " | 1845-46. |
| | Eskdale Foot | ... | " | 1846-49. |
| | " Head | ... | " | 1847-53 T |
| | Esk House | 2550 | I. Fletcher, Esq. ... | C 1865- |
| | Gatesgarth | 326 | Dr. Miller..... | 1845-53 T |
| | Gillertwaite | 396? | " | 1846-51 T |
| | Great End | 3000 | I. Fletcher, Esq. ... | C 1865- |
| | Great Gable | 2925 | Dr. Miller..... | 1846-53 T |
| | Langdale Head..... | 250 | " | 1845-52 T |
| | Loweswater Lake | 336 | " | 1844-53 T |
| | Mosedale | 624 | I. Fletcher, Esq. ... | C 1865- |
| | Sea Fell Pike | 3200 | " | C 1864- |
| | " | 3166 | Dr. Miller..... | C 1846-53 imp. T |
| | Seathwaite..... | 422 | I. Fletcher, Esq. ... | C 1865- |
| † | " (10 in.) | 422 | Dr. Miller and Mr. Dixon | 1846- |
| | " (22 in.) | 405 | " | 1845-53 T |
| | Seatollar Common | 1388 | Dr. Miller..... | 1846-53 T |
| | Sparkling Tarn..... | 1900 | " | 1846-53 T |
| | Sprinkling Tarn | 1985 | I. Fletcher, Esq. ... | C 1864- |
| | Stonethwaite | 330 | " | C 1864- |
| | " | ... | Dr. Miller..... | C 1847-53 T |
| | Stonywath..... | ... | " | 1844 imp. |
| | Stye, The | 948 | " | 1850-53 |
| | " (Head Tarn) | 1472 | I. Fletcher, Esq. ... | C 1864- |
| | " | 1448 | Dr. Miller..... | C 1846-53 T imp |
| | Wastdale Head..... | 247 | I. Fletcher, Esq. ... | C 1864- |
| | " | 247 | Dr. Miller..... | C 1845-53 T |

CUMBERLAND.

| | | | | |
|--|------------------------|-----|-----------------------|-----------------|
| | Alston | ... | | 1851-52 imp. |
| | Brampton | ... | | 1851-imp. |
| | " (Croft House) | 370 | J. Coulthard, Esq.... | 1851-2, 1854-55 |
| | Carlisle | ... | | 1767 |
| | " | 40 | | 1851-53 |
| | " (Shaddongate)..... | 40 | Mr. Pitt | C 1801-24 T |
| | " (Cemetery) | 114 | Mr. Cameron | 1860- |
| | " (O. S. Office) | 123 | Capt. James, R.E. .. | 1859-61 T |

¹ A copy of the Table of the monthly fall at Dr. Miller's Mountain Stations in 1844 is very much wanted by Mr. Symons.

CUMBERLAND (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|-------|-----------------------------|------------|-------------------------|------------------------|
| | Carlisle (Harraby) | ... | J. Atkinson, Esq. ... | 1851 |
| | " (Scaleby) | 120? | R. A. Allison, Esq. ... | C 1863- |
| | " (Scotby) | 100 | Mr. J. Clark | 1851 |
| | Cockermouth | 127 | Dr. Miller | 1845-50 |
| | " | 158 | Dr. Dodgson | C 1861- |
| | " (8 ft.) | 164 | " | C 1864- |
| | " (Bridekirk) ... | ... | Rev. J. Carter. | |
| | " (Higham) | ... | T. A. Hoskins, Esq. | |
| | " (Whinfell Hall) .. | 266 | W. Robinson, Esq. | C 1856- |
| | " | ... | " | C 1829-33 T |
| | Derwentwater (Crow Park)... | ... | H. C. Marshall, Esq. | C 1864- |
| | Keswick | ... | Mr. Crosthwaite .. | C 1788-94 |
| † | " | 250 | " | 1845- |
| *B.A. | " | 250 | " | C 1865- |
| | " (Bassenthwaite Hall)... | 210? | Dr. Miller | 1847-52 |
| † | " (Mirehouse) | 300 | T. S. Spedding, Esq. | 1854- |
| | Lingmell | ... | Dr. Miller | 1850-53 |
| | Maryport (Tarnbank) | 225 | I. Fletcher, Esq. ... | C 1863- |
| | " | 230 | " | C 1863- |
| | " (Broughton Moor) .. | 410 | " | 1849-51 |
| | Penrith | ... | Mr. Bird | 1851-54 |
| | " (Crewgarth) | ... | J. P. Spedding, Esq. | 1850-52 |
| | " (Edenhall) | ... | Mr. Bowstead | C 1864- |
| | " (Greystoke) | ... | " | 1846-51 |
| | Silloth | 28 | Rev. F. Redford ... | C 1855- |
| | Tirrill | ... | " | 1845 total only. |
| | Whitbeck | ... | Rev. T. Ormandy ... | C 1864- |
| | Whitehaven | 90 | Dr. Miller | C 1833-53 |
| | " (Round Close) ... | 480 | " | 1846-48 |
| | " (St. James' Church) .. | 90 | " | 1844-53 T |
| | " (Bootle) | 87 | Rev. A Wilkin | C 1863- |
| | " (Braystones) ... | 36 | J. D. Watson, Esq. | C 1864- |
| | " (Floss, Cleator) .. | 240 | T. Ainsworth, Esq. | 1844-53, 1855-61, 1863 |
| | " (Holme Rook) ... | ... | Rev. C. Pratt. | |
| | Wigton | ... | Rev. R. Matthews . | 1845-52 |
| | " (Brookfield School) .. | ... | " | 1854- |
| | " | 130 | R. M. Liddbetter, Esq. | C 1861- |

DERBYSHIRE.

| | | | | |
|---|--------------------------|------|----------------------|----------------------|
| | Belper | ... | J. G. Jackson, Esq. | |
| | Buxton | ... | G. Drury, Esq. | C 1865- |
| | Chapel-en-le-Frith | 965 | M. S. & L. R. | 1840, 1844-47 |
| | " (Combs House) | ... | " | 1851-54, 1858- |
| | " (" Moss or Ridge) .. | 1669 | " | 1855 imp. |
| | " (" Reservoir) ... | 710 | " | 1847, 1851- |
| | " (" Soc. gauge) | 850 | " | 1840, 1844-47, 1850- |
| | Chatsworth | ... | Manchester Memoirs | 1844-47 |
| † | " | 404 | Mr. Stewart | 1777-93 |
| † | " | 404 | Mr. Taplin | C 1860-63 |
| | Chesterfield | 248 | M. S. & L. R. | 1865- |
| | " (Brampton) | ... | Rev. J. M. Mello ... | C 1855- |
| | " | ... | J. M. Hewitt, Esq. | C 1864- |
| | Derby | 140 | Mr. Swanwick | 1809-35 |
| | " | ... | " | 1837 |
| | " | 180 | J. Davis, Esq. | C 1843- |
| | " (All Saints Church)... | 349 | " | C 1862 T |
| | " (Mickleover) | ... | Dr. Hitchman. | |
| | " (Morley) | ... | Rev. S. Fox. | |

1865.

DERBYSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---|---------------------------------------|------------|-----------------------|------------------|
| | Derby (Ockbrook) | ... | Rev. M. A. Smelt... | C 1865- |
| | " (West Hallam) | ... | Rev. C. Newdigate | |
| | Doveridge | 270 | Hon. Rev. O. Forester | C 1861- |
| | Glossop (Hillfoot) | 500 | | 1839, 1840, 1842 |
| | " (Hurst) | ... | Mr. Kershaw | 1842-4 imp. |
| | " (" Brook) | 1500 | Manchester Memoirs | 1839-42 |
| | Hathersage (Bamford) | 300 | " | 1839-41 |
| | Hayfield (Kinder Scout) | 1600 | " | 1839-41 |
| | Matlock (Willersley Castle) | ... | P. Arkwright, Esq. | |
| | Norwood | 238 | M. S. & L. R. | 1858- |
| * | Sawley | 170? | Mr. Windle | C 1864- |
| | Spondon | 200? | T. C. Cade, Esq. ... | 1864- |
| | Stoney Middleton | ... | Rev. U. Smith | C 1865- |
| | Woodhead (Station) ¹ | 939 | M. S. & L. R. | C 1851- |
| | " (Black Clough) ... | 1700 | Manchester Memoirs | 1849-51 |

DEVONSHIRE.

| | | | | |
|---|--|------|------------------------|-----------------|
| | Bampton (Huntsam Court) | 584 | Miss Troyte | 1859-62 |
| | Barnstable | 31 | T. Mackrell, Esq.... | C 1857- |
| * | " (Bratton Fleming) | ... | Rev. H. S. Pinder . | C 1865- |
| | " (Braunton Lighthouse) | 40 | | 1855 imp. |
| | Bideford (Appledore ") | ... | | 1855 imp. |
| * | " (Buckish) | ... | Rev. J. H. Kirwan . | C 1865- |
| * | " (Northam) | ... | Rev. J. H. Gossett.. | C 1865- |
| † | Bovey Tracy | 96 | J. Divrett, Esq. | 1852, 1856- |
| | Buckfastleigh (Hawson) | ... | Mr. Scott | 1861 |
| | " (Holne) | 680 | Rev. T. Hullah | C 1851-56 T |
| | " | ... | F. Sullivan, Esq. | |
| | Buckland Monachorum
(Crapstone) | 500 | G. Leach, Esq. | 1857-58, 1860 T |
| | Chumleigh (Chawleigh) | ... | | 1857-59 |
| | " (Witheridge) | ... | | 1855 imp. |
| | Collumpton (Bradninch) ... | 250 | Mr. H. Matthews... | C 1841- |
| | " (Clyst Hydon)... | 200 | Rev. J. Huyshe | C 1847- |
| * | " (Strath Culme) .. | 200 | C. R. Collins, Esq. .. | C 1864- |
| | Dartmoor (Burrator, Sheepstor) | 950 | H. Terrell Esq..... | 1855-58 |
| † | " (Lee Moor) | 900 | H. H. Treby, Esq. .. | C 1860- |
| | " (Prison Roof) | 1400 | Dr. Roome | C 1853- |
| † | " (" Reservoir) . | 1400 | Mr. Watts | C 1862- |
| † | " (North Hessary Tor) | 1596 | " | C 1862- |
| | " (Prince Town) | 1360 | Mr. Windeatt | 1838-40 |
| | " (Rough Tor Consols) | 1200 | | |
| | Dawlish (Mamhead) | ... | Gardener's Chronicle | 1852 |
| † | " | 62 | P. J. Margary, Esq. | C 1857- |
| | Devonport | 118 | Mr. T. Lancaster .. | 1852-53 |
| | " (Stoke) | 195 | Mr. Mould | C 1817-29 T |
| | Exeter (Barnfield) | 146 | Dr. Shapter | 1847-58 |
| | " (Brampford Speke) ... | ... | W. H. Gamlen, Esq. | C 1865- |
| † | " (High Street) | 180 | W. H. Ellis, Esq.... | 1860- |
| * | " | 184 | " | C 1864- |
| † | " (Hooper) | ... | G. Kennaway, Esq. | C 1864- |
| † | " (Institution) | 155 | Mr. Parfitt | C 1817- |
| | " (Pen Leonard) | ... | Dr. Barham | 1840-42 |
| † | " (St. Leonards) | 140 | W. Vicary, Esq. ... | C 1861-64 T |
| † | " | 160 | " | C 1860-64 T |
| † | " | 141 | R. Dymond, Esq. .. | C 1860- |
| † | " (St. Thomas) | 50 | | C 1814-61 |

¹ See also Cheshire.

DEVONSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---------|------------------------------------|------------|----------------------------|---------------|
| † | Exmouth (Bystoke) | 280 | E. Divett, Esq. | C 1860-63 T |
| * B. A. | Hartland | ... | Rev. T. Chope | C 1864- |
| | Honiton | ... | | 1841 imp. |
| † | „ (Broadhembury) ... | 600 | Rev. W. Heberden | C 1837- |
| | „ (Otterhead) | ... | Miss Beadon | C 1856-63 T |
| | „ (Overday) | ... | R. T. Abraham, Esq. | 1862 |
| † | Ivybridge (Torrhill) | 240 | J. Widdicombe, Esq. | C 1857- |
| | Kentisbury (Westland Pound) | 930 | Mr. Smith | 1855 imp. |
| | Kingsbridge (The Knowle) ... | 143 | Mrs. Harris | C 1857- |
| | Ledford (Hexworthy) | ... | | C 1863- |
| | Milton Abbot (Beckwell) ... | ... | Mr. Easterbrook | C 1863 |
| † | „ (Edgecumbe) | ... | H. Clark, Esq. | 1860-63 T |
| | „ „ | ... | | 1832 |
| † | „ (Endsleigh) | ... | Mr. Cornelius | C 1863- |
| | Moreton Hampstead (Chagford) | 660 | R. L. Berry, Esq. | C 1862- |
| † | Newton Bushel (High Wick) | 250? | Dr. Barham | C 1851- |
| | North Tawton | 450 | | 1826-34, 1838 |
| | Plymouth | 30 | Dr. Huxham | 1731-35 imp. |
| | „ | 30 | Dr. Farr | 1767-68 |
| † | „ (Compton Hartley) | ... | Miss Molesworth ... | C 1864- |
| | „ (Flora Place) | ... | | 1841 imp. |
| | „ (Whimble Street) .. | ... | Mr. Jeffery | C 1864- |
| | „ (Ham) | 94 | Rev. C. T. Trelawney | C 1842- |
| † | Plympton St. M. (Goodamoor) | 580 | H. H. Treby, Esq. | C 1834- |
| † | „ (Ridgeway) | 116 | Miss Phillippa | C 1857- |
| † | „ (Saltram) | 96 | Mr. Snow | C 1855- |
| | Sidmouth | ... | Dr. Cullen | (1843-?) |
| | „ | ... | Dr. Mackenzie | C 1865- |
| | „ (Blackmoor) | 30 | W. Strahan, Esq. ... | C 1864- |
| * | „ (Salcomb Hill House) .. | 74 | A. North, Esq. | C 1861, 1863- |
| | South Molton (Castle Hill) ... | 150 | Mr. Saul | C 1851- |
| | „ (Meshaw) | 472 | Rev. W. H. Karslake .. | C 1861- |
| | South Sydenham | ... | | 1858 |
| | Tavistock | ... | Mr. Windeatt | 1838-42 |
| | „ | ... | Dr. Barram | 1840, 1842 |
| † | „ (Bradstone) | ... | Rep. Cor. Pol. Soc. | C 1844- |
| | „ (Library) | 273 | Mr. Merrifield | C 1865- |
| * | „ („ New) | ... | „ | C 1864- |
| * | „ (Mount Tavy) | ... | J. Carpenter, Esq. | C 1864- |
| † | Teignmouth | 61 | W. C. Lake, Esq. ... | C 1860-62 T |
| † | „ (Westbrook) ... | 50 | Miss Clark | C 1859- |
| | „ (Bishop's Teignton) .. | 100 | Rev. S. M. Scroggs. ... | C 1864- |
| | Tiverton (Cove) | 450 | W. N. Row, Esq. ... | C 1862- |
| | „ (Hayne) | 400 | W. H. Gamlen, Esq. | C 1853-64 T |
| | Topsham (Clyst St. George) .. | ... | Rev. H. Ellacombe. ... | C 1865- |
| * B. A. | Torquay (Lamorna) | 205 | W. Pengelly, Esq. ... | C 1864- |
| | „ (Melville) | ... | T. G. Braden, Esq. | ... |
| * | „ (South Town Villa) .. | ... | Rev. C. Malden | C 1865 T |
| † | „ (Woodfield) | 150 | E. Vivian, Esq. | 1860-1, 1864 |
| | Torrington (Great) | 450 | Rev. S. Buckland ... | C 1863- |

DORSETSHIRE.

| | | | |
|--------------------------------|------|-----------------------|--------------|
| Beaminstor (Netherbury) ... | 120? | Rev. C. B. Mount... | C 1857-65 T |
| Blandford | ... | W. Shipp, Esq. | C 1864- |
| Bridport (The Cedars) | 85 | A. Stephens, Esq. ... | C 1855- |
| Cerne Abbas (Melbury House) .. | ... | Earl of Ilchester ... | 1852-54 imp. |

DORSETSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|--------|----------------------------|------------|------------------------|---------------|
| * | Dorchester..... | ... | J. Jowett, Esq. | C 1865- |
| | " (Little Bridy) | 348 | H. S. Eaton, Esq. | C 1855- |
| | " (Upwey) | 70 | J. Miller, Esq. | C 1862- |
| | " (West Lodge) | ... | Mrs. Wyndham .. | 1852-53 imp. |
| | " (Abbotsbury) | ... | Earl of Ilchester. | |
| | Forde Abbey [Chard] | ... | G. Miles, Esq. | C 1861-64 T |
| | Gillingham | 110? | T. Thompson, Esq. | C 1832- imp. |
| | Portland (The Grove) | 220 | Dr. Houghton | C 1851-58 T |
| | " (Breakwater) | 52 | J. T. Leather, Esq. | C 1856- |
| | Shaftesbury | ... | T. Ackland, Esq. ... | C 1864- |
| * B.A. | " (Fontmell Magna) | ... | W. J. Salkeld, Esq. | C 1864 T imp. |
| | " (Sutton Waldron) | ... | Archdeacon Huxtable | C 1864 T |
| | Sherborne | 120 | J. Kidd, Esq. | C 1863- |
| | Wareham (Encombe) | 150 | O. W. Farrer, Esq. .. | C 1860- |
| * | Wimborne (Chalbury) | ... | Rev. G. H. Billington | C 1865- |

DURHAM.

| | | | | |
|---|-------------------------------------|-----|-----------------------|----------------|
| | Bishopwearmouth | 130 | Dr. Ogden | C 1835- |
| | Darlington | ... | | 1734-35 imp. |
| | " | 140 | Mr. Richardson ... | C 1859- |
| | " (Long Newton) | ... | F. H. Dyke, Esq. | |
| * | " (Dinsdale) | ... | Rev. J. W. Smith... | C 1865- |
| | " (Raby Castle) | ... | Mr. McIntosh. | |
| | Durham | 339 | M. R. Dolman, Esq. | 1850- |
| | " (Esk) | ... | Rev. T. Chevallier .. | |
| | " (Ushaw College) | 600 | Rev. J. Gillow | C 1861- |
| | Gateshead (Burghfield Grange) | 68 | G. Wailes, Esq. ... | 1864- |
| | Seabam Hall | 100 | R. Draper, Esq. ... | C 1862- |
| | Sunderland (Esplanade) | ... | Dr. Pyle. | |
| † | " (Field House) | 85 | Rev. G. Iliff | 1854- |
| † | " (Hendon Hill) | 120 | J. W. Mounsey, Esq. | C 1862- |
| † | " (West Hendon) | 125 | T. W. Backhouse, Esq. | C 1859-60 imp. |
| † | " | 125 | " | C 1860- |
| | " | 130 | | 1856-59 |
| | Washington | 120 | J. Watson, Esq. ... | 1856-58, 1860 |
| | Winston (Stubb House) | 458 | T. Dodgson, Esq. ... | 1856- |
| | Whorlton | ... | Rev. A. Headlam .. | |

ESSEX.

| | | | | |
|--------|--------------------------------|------|-------------------------|-------------|
| * B.A. | Billericay | ... | F. Carter, Esq. | C 1865- |
| | Braintree (Bocking) | 200 | S. Tabor, Esq. | C 1851- |
| | Colchester | ... | Army Med. Corps. | |
| * | " (Broom Hill House) | 55? | Capt. Walker | C 1864- |
| | " (Birch Hall) | ... | C. G. Round, Esq. ... | C 1865- |
| | " (Frating) | 80? | Rev. R. Duffield ... | C 1854-62 T |
| | Dunmow | 234 | H. E. Cockayne, Esq. | C 1851- |
| | Epping | 360 | H. Doubleday, Esq. | C 1822- |
| | Harlow (Sheering) | 100? | Rev. E. Hill | C 1863- |
| | Hedingham Castle | ... | L. A. Majendie, Esq. | 1864- |
| † | Leyton | 93 | J. G. Barclay, Esq. ... | 1861, 1863 |
| | Plaistow | ... | L. Howard, Esq. ... | 1806-12 |
| | Rochford (Clements Hall) | 25? | A. Holt White, Esq. | C 1863- |
| | Romford (Upminster) | ... | Rev. W. Derham ... | 1697-1716 |
| | Saffron-Walden (Ashdon) | 300 | Rev. J. T. Walker .. | C 1858- |
| | Witham (Dorwards Hall) | 20 | H. Dixon, Esq. | 1847- |

GLOUCESTERSHIRE.

| | | | |
|----------------|-----|----------------------|---------|
| Berkeley | ... | Rev. C. T. Pratt ... | C 1865- |
| Bristol | ... | | 1774-78 |

GLOUCESTERSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---|---------------------------------------|------------|------------------------|-------------|
| | Bristol (Institution) | 98 | Rev. C. T. Pratt .. | 1860-61 |
| | " (Park Row) | 140 | C. W. Bragge, Esq. | C 1859- |
| | " (Small Street) | 40 | | C 1855- |
| * | Cheltenham (Charlton Kings) | ... | Rev. F. H. Potter .. | C 1864- |
| | " " | ... | Dr. Williams | C 1864- |
| | " (Hospital) | 200 | Mr. Moss | 1833-39 |
| | Cirencester (Further Barton) | 446 | Mr. Moon | C 1862-63 T |
| | " (Royal Agr. Coll.) | ... | T. C. Brown, Esq. .. | C 1844- |
| | Clifton | 192 | W. C. Burder, Esq. | C 1853-65 T |
| | " | 242 | " | C 1853-65 T |
| | Frampton-on-Severn (Saul Lodge) | 42 | W. B. Clegram, Esq. | C 1862- |
| | Gloucester (Ayslum) | 100 | Dr. Williams | 1860-62 |
| | " (Barnwood House) | ... | Dr. Wood | 1864- |
| | " (Clarence Street) .. | 60 | C. J. Fowler, Esq. ... | 1858-59 |
| | " (Gas Works) | ... | R. Spinney, Esq. ... | 1837 imp. |
| | " (Quedgeley) | 100? | J. C. Hayward, Esq. | 1849- |
| | " (The Spa) | 50 | A. Price, Esq. | C 1860- |
| | " " | 84 | | C 1864- |
| | " (Twigworth) | 50 | W. B. Clegram, Esq. | 1858-62 T |
| | " (Water Works) ... | ... | Mr. Richardson. | |
| | " (Whitecomb Court) .. | ... | A. Bubb, Esq. | |
| * | Stroud (Bedford Street) | ... | J. Bateman, Esq. ... | C 1865- |
| | " | ... | Dr. Paine. | |

HAMPSHIRE.

| | | | | |
|--|--------------------------------|-----|------------------------|---------------------|
| | Aldershot | 325 | J. Arnold, Esq. | C 1858- |
| | " (25 ft.) | 350 | " | C 1864- |
| | " (Bourley) | 370 | E. Shaw, Esq. | 1864- |
| | Alresford (Arle Bury) | 80? | F. Marx, Esq. | 1862- |
| | " (New) | ... | Mr. Fielder | 1861 |
| | Alton (Newton Valence) .. | ... | Rev. J. White. | |
| | " | ... | W. Curtis, Esq. | |
| | " (Medsted) | 680 | Rev. M. A. Smelt. ... | C 1863-64 T |
| | Andover | ... | Mr. Holt | C 1785-89 |
| | " (Abbots Ann) | 177 | Rev. F. H. White .. | C 1847-62 T |
| | " (Fyfield) | ... | | 1784-92 |
| | Basingstoke (Sherborne) .. | ... | Rev. C. H. Cholmely | |
| | " (Strathfield Turgess) .. | 169 | Rev. C. H. Griffith .. | 1862- |
| | Christchurch (Bournemouth) .. | 30? | Dr. Falls | 1862-63 |
| | " (Mudieford House) .. | 10 | F. Moser, Esq. | 1864- |
| | Fareham | 8 | R. Porter, jun., Esq. | C 1861- |
| | " (North Brook) | 26 | H. Sharland, Esq. ... | C 1860- |
| | Gosport | ... | | 1837-40, 1842, 1856 |
| | " | ... | J. H. Maverly, Esq. | 1841-42 |
| | Havant (Leigh Park) | 40? | W. H. Stone, Esq. ... | C 1864- |
| | Isle of Wight (Carisbrook) ... | ... | | 1847-48 imp. |
| | " (Newport) | 24 | J. C. Bloxam, Esq. ... | 1841-56 |
| | " (Osborne) | 172 | J. R. Mann, Esq. ... | 1852-56 imp. |
| | " (") | 172 | " | C 1858- |
| | " (Parkhurst) | ... | Army Med. Corps. | |
| | " (Ryde) | 110 | B. Barrow, Esq. ... | 1860 |
| | " (") | 15 | R. Taylor, Esq. ... | C 1860- |
| | " (St. Lawrence) .. | ... | Rev. C. Malden. | C 1865- |
| | " (") | ... | W. T. King, Esq. ... | C 1865- |
| | " (Ventnor) | 150 | Dr. Martin | C 1840- |
| | Lyndhurst | ... | | 1860, 62, 63 |
| | Petersfield | ... | Dr. Peskett | C 1860- |

HAMPSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---|-------------------------------|------------|-----------------------|-------------|
| | Petersfield (Heath Lodge) ... | 200 | Rev. M. A. Smelt ... | C 1857-63 T |
| | " (Liss) ... | 200 | Rev. H. Haigh ... | C 1864- |
| | " (Liss) ... | ... | G. E. Coryton, Esq. | 1853- |
| | Portsmouth ... | ... | Army Med. Corps. | |
| | Selborne (The Wakes) ... | 500? | Gilbert White, Esq. | C 1780-93 T |
| | " () ... | 500? | T. Bell, Esq. | C 1851- |
| | Southampton (Gas Works)... | 20 | Mr. Sharp ... | C 1848-61 |
| | " (O. S. O.) ... | 74 | Col. Sir H. James... | 1855- |
| | " () ... | 92 | | 1855- |
| * | " (Bassett Wood) ... | 230 | J. Bullar, Esq. | C 1865- |
| | " (Cadland) ... | ... | E. Drummond, Esq. | (1863-) |
| | " (Eling House) ... | 15 | W. C. Spooner, Esq. | |
| | " (Netley) ... | ... | Army Med. Corps... | 1848- |
| | " (Shirley Warren) ... | 102? | R. C. Hankinson, Esq. | 1862- |
| | Winchester (Gas Works).... | 156 | Mr. Sharp ... | C 1842-47 T |
| | " (Hursley) ... | 300? | Rev. S. M. Scroggs . | C 1861-63 T |
| | " (Itchen Abbas)... | ... | Rev. W. W. Spicer . | 1850-62 |
| | " (Otterbourne) ... | 112 | J. B. Yonge, Esq.... | 1864- |
| | " | ... | Army Med. Corps. | |

HEREFORDSHIRE.

| | | | | |
|---|-------------------------------|------|------------------------|---------------|
| * | Hereford (Blue School) | 158 | E. J. Isbell, Esq. ... | C 1863- |
| * | " (Eign Hill) ... | ... | W. Cook, Esq. | C 1864- |
| * | " (Broomy Hill) ... | 194 | T. Curley, Esq. | C 1864- |
| | " (Infirmary)..... | 160 | A. Thompson, Esq. . | 1858, 1861-3. |
| | " | ... | H. Lawson, Esq. ... | 1836-41 |
| | " (Pool Cottage) ... | 450 | J. Pendergrass, Esq. | C 1818-43 T |
| | " (Stretton)..... | 250? | Rev. H. C. Key | 1860- |
| | Kington (Tittle or Burches) . | ... | R. R. Boddington, Esq. | C 1841-52 |
| | Leominster (Leysters) ... | 700? | Rev. T. S. Hewitt ... | 1861- |
| | " (West Lodge) ... | 229 | E. P. Southall, Esq. | C 1857- |
| | Ross (Rocklands)..... | 150? | J. M. Herbert, Esq. | 1852 |

HERTFORDSHIRE.

| | | | | |
|--|------------------------------------|------|----------------------|---------------|
| | Baldock (Hinxworth) | ... | | 1856-57 imp. |
| | Berkhamstead..... | 370 | W. Squire, Esq. ... | C 1848- |
| | Buntingford (Aspeden) | ... | Rev. A. P. Sanderson | C 1865- |
| | Chipping Barnet (Totteridge Park). | ... | | |
| | Hatfield House | ... | | 1852, 1854-56 |
| | Hemel Hempstead (Nash Mills) | 250 | J. Evans, Esq. | C 1833- |
| | " (Kensworth) | 90? | T. Jones, Esq. | C 1864 |
| | Hertford (Bayfordbury) | 250 | W. C. Baker, Esq. . | C 1859- |
| | " (Parkgate)..... | ... | Rev. R. P. Davies . | C 1864- |
| | Hitchin | 242 | W. Lucas, Esq..... | 1850- |
| | Hoddesdon (Fields Weir) ... | 82 | N. Beardmore, Esq. | 1861- |
| | Royston..... | 266 | H. Wortham, Esq. . | C 1842- |
| | St. Albans (Gorhambury) ... | ... | Mr. Bogue..... | C 1853- |
| | " (Rothamstead) ... | ... | J. B. Lawes, Esq.... | |
| | " (" small gauge) | ... | " | |
| | Stevenage | ... | C. B. Pearson, Esq. | 1852-55, 1859 |
| | " (Woodfield) | 300 | J. B. Denton, Esq. . | 1864- |
| | Ware (Youngsbury) | ... | | 1787-91 |
| | Watford (Bourne End) | 300? | R. Littleboy, Esq. . | 1854, 56-59 T |
| | " (Bushey Heath) ... | ... | Capt. Beaufoy | 1818-20 imp. |
| | " (" Roof) | ... | " | 1820 imp. |
| | " (Eastbury) | 380? | D. Carnegie, Esq. . | C 1861- |
| | " (Hunton Bridge) ... | 200? | R. Littleboy, Esq. . | C 1860-64 T |
| | " (Watford House) ... | 190 | R. Clutterbuck, Esq. | C 1857- |
| | Welwyn (The Hall)..... | ... | C. Trueman, Esq. | |

HUNTINGDONSHIRE.

| | Station. | Elevation. | Observer. | Period. |
|--|-----------------------------|------------|-----------------------|--------------|
| | Conington Rect. [Peterboro] | ... | Rev. G. Heathcote . | 1864- |
| | Huntingdon (Ramsey) | ... | Lady Bayning | 1836-42 imp. |
| | " (Wistow) | ... | Rev. T. Woodruff... C | 1864- |
| | Kimbolton (Hamerton) | 170 | Rev. A. P. Stopford | C 1853- |
| | St. Ives (Earith) | ... | Mr. Brown | 1862-63 |
| | St. Neots (Tetworth) | ... | H. M. Kaye, Esq. ... | 1862- |
| | " (Warelesley) | 200 | Rev. W. M. H. Elwyn. | C 1863- |

KENT.

| | | | | |
|---------|------------------------------|------|------------------------|------------------|
| † | Bexley Heath (Danson Hall). | ... | Mr. H. Johnston. | |
| | " (Welling) | 150 | H. S. Wollaston, Esq. | 1852- |
| | Canterbury | ... | Army Med. Corps. | |
| | " (Chartham) | ... | C. J. Drew, Esq. . . | 1864- |
| | " (Patricbourne)..... | 97 | Rev. M. A. Smelt ... | C 1855-56 T |
| | Chatham | ... | Army Med. Corps. | |
| | Chislehurst | ... | | 1729-30, 1732-35 |
| | Crossness | 10 | J. W. Bazalgette, Esq. | C 1864- |
| | Dover | ... | Army Med. Corps. | |
| | " | ... | Mr. Mantell | 1789-93 imp. |
| † | " (Castle Keep) | 512 | H. J. Poulter, Esq. | 1863- |
| † | " (Castle Street) | 16 | " | 1859-61, 1864- |
| | Edenbridge (New Falconhurst) | 400 | J. G. Talbot, Esq. . | 1864- |
| | Greenwich | ... | W. Rogerson, Esq. . | 1833, 1838-51 |
| | " (Observatory) | 155 | J. Glaisher, Esq. ... | C 1815- |
| | " (, , various gauges) | ... | " | Various. |
| | Hythe | ... | H. Mackeson, Esq. | |
| | " (Horton Park) | 280? | J. Kirkpatrick, Esq. | C 1858- |
| | " (Saltwood) | ... | G. S. Court, Esq. | |
| | Lamberhurst (Court Lodge) . | 200? | W. C. Morland, Esq | C 1862- |
| | " (Scotney Castle) | ... | E. Hussey, Esq. ... | 1862- imp. |
| | Lewisham | ... | J. Glaisher, Esq. | |
| | Maidstone | ... | F. Dobell, Esq. | 1856- |
| | " (Fant Road) | 60 | J. H. Baverstock, Esq. | C 1857- |
| | " | ... | Dr. Fielding | C 1848-57 T |
| *† B.A. | Margate (Acol) | 60 | E. S. Lendon, Esq. . | C 1864- |
| *† B.A. | " (R. Sea-B. Infirmary) | 25 | F. W. Maude, Esq. . | C 1864- |
| | Ramsgate (Trafalgar Place) . | ... | C. J. Fowler, Esq. . | 1860 imp. |
| † | " | ... | R. Cramp, Esq. | |
| * | Sandgate | 25 | T. Du Boulay, Esq. | C 1864- |
| | Seven Oaks (River Head) ... | ... | Rev. J. B. Murdoch | C 1865- |
| † | " (River Hill) | 520 | J. T. Rogers, Esq. . | 1860- |
| | Sheerness | ... | Army Med. Corps. | |
| | Shorncliffe | ... | " | |
| | Staplehurst (Hunton Court) . | ... | Mr. P. Goddard ... | 1858- |
| | " (Linton Park) ... | 200? | Mr. J. Robson | C 1855- |
| | Tunbridge | 125 | Dr. Fielding | C 1857- |
| | " | ... | | 1840, 1848-49 |
| | " Wells | 80 | " | 1840-43 imp. |
| | Walmer | ... | Army Med. Corps. | |
| † | Westerham (Chartwell) | 400 | J. C. Colquhoun, Esq. | C 1862- |
| † | West Wickham | 300 | Rev. J. T. Austen ... | C 1848- |
| | " | 500? | W. Steuart, Esq. ... | C 1861- |
| | Woolwich | ... | Army Med. Corps. | |

LANCASHIRE.

| | | | | |
|--|-------------------------------|-----|-----------------------|---------|
| | Blackpool (South Shore) | 29 | G. Sharples, Esq. ... | C 1855- |
| | Bolton-le-Moors (The Folds) | 286 | H. H. Watson, Esq. | 1831- |
| | " (Belmont) ... | 800 | H. Baylis, Esq. | C 1843- |
| | " (, Old Lyons) | ... | | 1844 |

LANCASHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---|------------------------------|-----------------|-----------------------------------|--------------------------------|
| | Bolton-le-Moors (Heaton) ... | 500 | H. Baylis, Esq. | C 1859- |
| | " (Vale Bank) | 300 | J. Watkins, Esq. ... | C 1863- |
| | Broughton in Furness. | | | |
| | Burnley (Townley) | ... | R. Townley, Esq. | 1677-86, 1689-93,
1697-1703 |
| | Bury (Greenbank) | 450 | W. Wanklyn, Esq. . | 1861-63 |
| | " | 313 | T. Norris, Esq. | 1830-45 T |
| | " (Rock Street) | 320 | T.R. Croasdale, Esq. | 1861, 1863 |
| | " | | T. Norris, Esq. | 1797-1801 |
| † | Cartmel (Pit Farm) | 170 | J. B. Binyon, Esq. . | 1861-63 |
| † | " (Allithwaite) | 88 | Mr. Nash | C 1860- |
| | " (Aynesome) | 60 | H. Remington, Esq. | C 1854- |
| | " (Backbarrow) | ... | D. Ainsworth, Esq. | |
| | " (Grange) | 25 | A. Beardsley, Esq. . | 1864- |
| † | " (Holker) | 155 | Mr. Wilson | C 1849- |
| | Clitheroe (Downham Hall)... | 474 | R. Assheton, Esq. ... | C 1855- |
| † | Coniston | 150 | J. G. Marshall, Esq. | 1850- |
| * | " | ... | R. J. Bywater, Esq. | C 1865- |
| | Dalton | ... | | 1854 imp. |
| | " (Rampside) | 34 ² | Rev. W. Dawson ... | 1853-57 |
| | Garstang (Bleasdale) | 600 | J. Hill, Esq. | C 1860-62 T |
| | " (Vale House) | 455 | J. Jackson, Esq. ... | C 1863- |
| | Lancaster | ... | | 1800-02, 1804-17 |
| | " | 30 | Rev. A. Christopher-
son | C 1849-51 T |
| | " (South Road) | 114 | W. Roper, Esq. ... | 1861- |
| † | " (Caton) | 120 | Rev. A. Christopher-
son | C 1852- |
| | " (Hest Bank) | 82 | R. B. Peacock, Esq. | 1860-63 |
| | " (Hornby Castle) .. | 103 | C.H. Lethbridge, Esq. | 1864- |
| | " | ... | Dr. Campbell | 1784-93 |
| | Liverpool | ... | | 1826 imp. |
| | " | ... | | 1845 |
| | " (Dock Offices) | ... | Mr. Hutchinson ... | 1775-1792 |
| | " (Starfield) | ... | W. Lassell, Esq. ... | 1842 |
| | " (Brook) | ... | W. Lassell, jun., Esq. | 1861-63 T |
| | " (Lord Street) | ... | Mr. Abrahams | 1840-41 |
| | " (Observatory) | 23 | J. Hartnup, Esq. ... | C 1864- |
| | " (") | 52 | " | 1846- |
| | " (Sandfield Park) .. | ... | W. Lassell, Esq. ... | 1860 T |
| | " (Walton) | ... | Mr. Holt | C 1791-1801 |
| | " | ... | | 1838 imp. |
| | " | ... | | 1802-04 |
| | " | ... | | 1784-92, totals. |
| | Manchester | ... | Nicholson's Journal | 1808-10 |
| | " | ... | Dr. Dalton | 1794-1840 |
| | " (Market Street) .. | ... | J. Casartelli, Esq. ... | 1830-53 T |
| | " (Piccadilly) | 194 | M. S. & L. R. | 1850- |
| | " (Ardwick) | 130 | J. Casartelli, Esq. ... | C 1853- |
| | " (" Green) | ... | L. Bucham, Esq. ... | 1825-39 T |
| | " (Crumpsal) | ... | | |
| | " (Denton) | 324 | J. F. Bateman, Esq. | 1854- |
| | " (Eccles) | 115 | T. Mackereth, Esq. | C 1861- |
| | " (Fairfield) | 312 | M. S. & L. R. | 1840, 1845-47, 1851- |
| | " (" Soc. Gauge) .. | 320 | " | 1845-47 |
| | " (Gorton) | 263 | J. F. Bateman, Esq. | 1854- |
| | " (Holme) | ... | G. Lloyd, Esq. | 1765-69 |
| † | " (Old Trafford) .. | 106 | G. V. Vernon, Esq. | 1850- |
| † | " (") | 104 | J. Curtis, Esq. | C 1862- |
| | " (Outwood) | 295 | W. Horrocks, Esq. | 1860- |

LANCASHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|-------|------------------------------|------------|-----------------------|---------------------|
| | Manchester (Rhodes Wood). | 520 | J. F. Bateman, Esq. | 1855- |
| | " (Sale) | 134 | J. Curtis, Esq. | 1855-61 T |
| | " (Salford) | ... | Mr. Walker | 1786-93 |
| | Middleton (Slattocks) | 450 | Manchester Mem.... | 1833-40, 1845-47 |
| | " (" Soc. gauge)... | 450 | " | 1844 |
| | Oldham (Brushes Clough)... | 950 | J. Taylor, Esq. | 1861- |
| | " (Gas Works) | 600 | " | 1860- |
| † | " (Royton) | 484 | Mr. Heap | 1836- |
| *B.A. | " (") | 480 | " | C 1865- |
| | " (Strines Dale)..... | 800 | J. Taylor, Esq. | 1859- |
| | " (Waterhouses) .. | 345 | M. S. & L. R..... | 1845-47, 1850- imp. |
| | Ormskirk (Rufford)..... | 38 | J. Porter, Esq. | C 1847- |
| | Preston (Fishwick) | 154 | T. Oddie, Esq. | C 1850- |
| | " (Holme Slack) | 143 | J. Newton, Esq. ... | C 1861- |
| | " (Howick) | 72 | T. Norris, Esq. | C 1845- |
| | " (House of Correction) | 140 | Mr. Hesketh | C 1849- |
| | " (") | 187 | " | C 1848- |
| | " | ... | Army Med. Corps. | |
| | Radcliffe (Mount Sion) | 250 | H. Eaton, Esq. | 1862- |
| | Rochdale | ... | M. S. & L. R..... | 1863- |
| † | " (Castleton Moor)... | 475 | Rev. J. C. Bates ... | C 1863- |
| *† | " (" Exp. gauges) | ... | " | Various. |
| | " (Castle Hill) | 500 | Mr. Ecroyd | 1832-47 |
| | " (Heywood W. W. Res.) | 900 | C. E. Cawley, Esq.... | C 1848- |
| | " (Moss Lock) | 500 | Manchester Mem. | 1825-40, 1844-47 |
| | " (" Soc. gauge) ... | 500 | " | 1844, 1846, 1847 |
| | " | ... | " | 1843 |
| | Southport (Virginia Farm)... | ... | R. Stokes, Esq. | C 1861-63 T |
| | Todds Brook | 620 | Manchester Mem.... | 1847 |
| *B.A. | Ulverston | 98 | J. H. Matthews, Esq. | C 1864- |
| | " | ... | " | 1852-58 imp. |
| | Waith Sutton | ... | Manchester Mem.... | 1789-93 |
| | Warrington | 33 | T. G. Rylands, Esq. | 1849-55 |
| | " (Penketh School) .. | ... | L. J. Reynolds, Esq. | C 1865- |
| | " (Winwick) | ... | E. Rothwell, Esq. ... | 1844 imp. |
| | " (Walton Lea) | ... | G. Crosfield, Esq. | |
| | Whalley (Stonyhurst) | 381 | Rev. W. Sidgreaves | C 1846- |
| | Wigan (Waterworks Reserv.) | 225 | J. L. Hunter, Esq. . | C 1863- |
| | " (Standish) | 300 | " | C 1858- |
| † | Windermere (Fell Foot)..... | ... | Manchester Mem.... | 1788-91 |
| | " (Wray Castle) ... | 250 | Dr. Dawson | C 1849- |
| | Yealand [Burton on Kendal]. | ... | " | 1826 imp. |

LEICESTERSHIRE.

| | | | | |
|--------|------------------------------|------|-----------------------|------------------|
| † | Appleby School | 340 | Rev. B. F. Falkner | C 1864- |
| | Belvoir Castle [Grantham]... | 237 | W. Ingram, Esq. ... | 1855- |
| | Leicester (Museum)..... | ... | J. Payne, Esq. | 1856-63 imp. |
| † | " (Hotel Street) | 220? | H. Billson, Esq. | C 1861- |
| | Loughborough (Emanl. Rect.) | 150? | Rev. R. J. Bunch ... | C 1861- |
| | " (Belton) | 300? | Rev. R. Dalby | C 1863- |
| | " (Rothley) | 210 | Rev. R. Burton | C 1860- |
| * | " (Woodhouse)..... | ... | Rev. J. Hiley | C 1865- |
| † | Market Harbro' (Fleckney)... | ... | J. B. Putt, Esq. ... | C 1863- |
| | Melton Mowbray | ... | Rev. C. A. Holmes | C 1861- |
| | " (Dalby Hall) | ... | E. B. Hartopp, Esq. | C 1863- |
| | " (Waltham) | 540? | Rev. G. E. Gillett... | C 1860- |
| *†B.A. | Owston [Oakham] | 580? | Miss Gilford | C 1864- |
| † | Thornton (Reservoir) | 420? | J. Bevins, Esq. | C 1855- |
| * | " (Vicarage) | 500? | Rev. R. S. Adams... | C 1857 T imp. |
| † | Wigston Grange | 220 | T. Burgess, Esq. ... | C 1835-43, 1845- |

LINCOLNSHIRE.

| | Station. | Elevation. | Observer. | Period. |
|---|---------------------------------------|------------|------------------------|------------------|
| | Boston | 10 | Dr. Adam | C 1864- |
| | " | 10 | W. Veall, Esq. | 1830-56, 1860-64 |
| | Brigg | 16 | M. S. & L. R. | C 1859- |
| | " (Appleby Hall) | ... | Mr. Usher | 1849-55 |
| | " (" Vicarage) | ... | Rev. J. E. Cross ... | 1858- |
| | " (Barnetby) | 51 | M. S. & L. R. | C 1859- |
| | " (Ferriby) | ... | Nicholson's Journ. . | 1808-10 |
| | " (" Sluice) | ... | Mr. Smith | C 1860- |
| | Gainsborough (Belmont Ho.) | 38 | T. Dyson, Esq. | C 1851- |
| | " | 76 | M. S. & L. R. | C 1859- |
| | " (Gate Burton) | 96 | " | 1860- |
| | " (Stockwith) | 21 | " | 1855- |
| † | Grantham | 179 | J. W. Jeans, Esq. ... | C 1851- |
| | " | ... | Mr. Read | 1851 |
| | Grimsby | 42 | M. S. & L. R. | C 1859- |
| | Horncastle (Vicarage) | ... | Rev. W. H. Milner .. | C 1863- |
| | " | ... | Nicholson's Journ. . | 1808-10 |
| | " (Minting Vicarage) | ... | Rev. F. Bashforth. . | |
| | Lincoln | 26 | M. S. & L. R. | C 1859- |
| | " (Coleby) | 100? | Rev. T. T. Penrose .. | 1855-61 |
| † | Market Deeping (Greatford Hall) | ... | Capt. Peacock | 1860- |
| † | " (Wytham on the Hill) | ... | Gen. Johnson | C 1820-62 T |
| * | " (") | ... | A. C. Johnson, Esq. . | C 1864- |
| | Market Rasen | 100 | M. S. & L. R. | C 1859- |
| | New Holland | 18 | " | C 1859- |
| | Sleaford | 52 | Mr. B. Heald | 1864- |
| | " | 46 | Rev. H. S. Neucatre .. | 1826-39 T |
| | " (Heydour Vicarage) | ... | Rev. Gordon Decdes .. | C 1865- |
| | " (South Kyme) | 9 | Rev. H. S. Neucatre .. | C 1840- |
| * | Spilsby (Welton-le-Marsh) ... | 80? | Rev. A. Wright | C 1864- |
| | Stubton [Newark] | ... | G. Nevile, Esq. | C 1862- |
| | Wainfleet (Croft) | ... | Rev. A. Wright | 1862- |

MIDDLESEX.

| | | | | |
|----|-------------------------------|------|------------------------|----------------|
| *† | Camden Town | 100 | G. J. Symons, Esq. . | C 1858- |
| | Chiswick | ... | Royal Hort. Soc. ... | 1825- |
| † | Colney Hatch | ... | R. G. Rose, Esq. ... | 1857- |
| | Edmonton | ... | C. H. Adams, Esq. . | 1792-96 |
| | " | ... | " | 1811, 1816-40 |
| | " (Lower) | ... | Mr. J. Brown | C 1860- |
| | Enfield (Back Hill) | 89 | W. Mylne, Esq. ... | 1864- |
| | " (Vicarage) | 110 | Rev. J. M. Heath.... | 1849- |
| † | Finchley Road | 270 | G. W. Moon, Esq. ... | C 1860-61 T |
| † | " | 306 | " | C 1860-61 T |
| | Hackney | 40 | Dr. Tripe | 1856-58, 1860- |
| | Hammersmith | 12 | F. J. Burge, Esq. ... | 1856-58, 1860- |
| | Hampstead | 360 | R. Field, Esq. | C 1862- |
| | Harrow-on-the-Hill | 375? | Dr. Hewlett | 1864- |
| † | Highgate | 394 | J. Cutbush, Esq. ... | C 1862- |
| † | London (Bryanstone Square) .. | 93 | C. O. F. Cator, Esq. . | 1861- |
| | " (Chiswell Street) ... | ... | W. Fletcher, Esq. ... | 1850-59, 1861- |
| | " (Crane Court) | ... | Roy. Soc. Trans. ... | 1729-35 |
| | " (Gray's Inn Road) ... | 55 | Mr. Strachan | C 1862 T |
| | " (Guildhall) | 50 | W. Haywood, Esq. . | C 1857- |
| | " (") | 123 | " | C 1857- |
| | " (Hatton Garden) ... | ... | Mr. R. C. Woods ... | 1838 imp. |
| | " (Mile End) | ... | F. Charrington, Esq. . | C 1862- |
| | " (Offord Road) | 90 | Mr. Strachan | C 1864- |

MIDDLESEX (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|----|------------------------------------|------------|------------------------|---|
| | London, (Somerset House) ... | 150 | Philos. Trans. | 1774-81, 1787-1809,
1812-27, 1829-42 T |
| | „ (Spring Gardens) ... | 36 | J. W. Bazalgette, Esq. | 1863- |
| | „ („) ... | 95 | „ | 1863 |
| | „ („) ... | 95 | „ | 1863 |
| | „ (Temple Bar) ... | ... | Bent's Met. Jour. .. | 1795-1807 |
| | „ (Westminster Abbey) ... | ... | Dr. Heberden | 1766-67 imp. |
| | „ („ House) ... | 65 ? | „ | 1766-67 imp. |
| | „ („ Garden) ... | 25 ? | „ | 1766-67 imp. |
| | „ (Whitehall) | ... | J. C. Haile, Esq. ... | C 1854-60 |
| | „ | ... | Nicholson's Journ. | 1808-10 |
| | „ | ... | | 1817-21 |
| | „ | ... | Lady Bayning | 1836-42 imp. |
| *† | Notting Hill | ... | S. B. Blunt, Esq. ... | C 1865- |
| | Paddington | ... | | 1854-56 |
| | Poplar | 25 | Mr. Gaster | C 1862-63 T |
| | St. John's Wood (Lit. Soc.)... 161 | ... | H. J. Montague, Esq. | 1857- |
| | „ (Melina Place) ... | ... | G. Leach, Esq. | 1852-57 imp. |
| | Spring Grove | 70 | T. E. Wyatt, Esq. ... | C 1864- |
| | Tottenham (Vicarage) | ... | Rev. J. S. Winter... C | 1861-62 T |
| | „ | 60 | Fowler | 1842-45- |
| | „ (Lordship Lane) ... | ... | W. D. Howard, Esq. | 1847- |
| | Twickenham (Observatory)... 24 | ... | A. Wiss, Esq. | C 1863- |
| | Uxbridge (Harefield Park)... .. | ... | W. Vernon, Esq. ... | C 1864- |
| | Winchmore Hill | ... | Mrs. Feltham | C 1858- |

MONMOUTHSHIRE.

| | | | | |
|---|---------------------------|------|----------------------|---------|
| | Abergavenny | ... | Dr. M'Cullough ... | C 1863- |
| | Chepstow | 50 | J. G. Wood, Esq. ... | C 1861- |
| | Monmouth | ... | | 1859 |
| * | Newport (Abercarn) | 160 | Rev. D. Charles .. | C 1864- |
| | „ (Glanusk Park) ... | ... | Sir J. Bailey, Bart. | |
| * | „ (Isca Foundry) | ... | J. Laybourn, Esq. | C 1865- |
| * | „ (Llanfrehfa Grange) ... | 360 | F. J. Mitchell, Esq. | C 1865- |
| | Tredegar (Blaina) | 1100 | H. Soper, Esq. | C 1863- |

NORFOLK.

| | | | | |
|---|----------------------------------|------|----------------------|----------------|
| | Acle | ... | Rev. R. W. Kerrison | C 1865- |
| | Cromer | ... | — Coper, Esq. | |
| | Diss | 110 | Dr. Stewart | C 1860- |
| | „ | 180 | „ | 1862-63 |
| | „ (Dickleborough) | ... | | 1840 imp. |
| * | Downham Market (Bexwell) .. | ... | Rev. E. J. Howman | C 1864- |
| | „ „ (Fincham) ... | 60 ? | Rev. W. Blyth | 1864- |
| | East Dereham (Mattishall)... 155 | ... | Rev. J. M. Du Port | C 1863- |
| | Hunstanton | 60 | Mr. Rippingale.... | 1856- |
| | Lynn (Hillington) | ... | Rev. H. Ffolkes ... | C 1865- |
| | Norwich | ... | Philos. Trans. | 1749-62 |
| | „ (Grey Friars) | 50 | W. Brooke, Esq. ... | C 1836- |
| | „ | ... | C. Evans, Esq. | |
| | „ (Institution) | 100 | W. Brooke, Esq. ... | 1861-62, 1864. |
| | „ (Carron House) ... | ... | J. J. Colman, Esq. | |
| | „ (Clenchwharton) ... | ... | Rev. F. Currie | 1853-59 |
| | „ (Cossey) | ... | H. Culley, Esq. ... | 1862- |
| | „ (Felthorpe) | ... | — Fellowes, Esq. ... | 1848-55 |
| | „ (Haverland) | ... | Lady Bayning | 1835-42 imp. |
| | „ (Honingham) | 110 | „ | 1843- |
| | „ (Stoke Holy Cross) ... | ... | J. J. Colman, Esq. | |
| | „ (Thorpe) | ... | W. Birkbeck, Esq. | |

NORFOLK (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|--------|-----------------------|------------|-----------------------|-----------|
| * | Reepham | ... | T. Aldate, Esq..... | C 1865- |
| * B.A. | Swaffham | ... | C. J. Drury, Esq. ... | C 1865- |
| | Thetford | 75 | Dr. Bailey..... | 1840-63 T |
| * B.A. | " (Watton) | ... | Mr. Martin | C 1865- |
| | Wells (Burnham) | 102 | H. E. Blyth, Esq.... | 1840- |
| | " (Egmere) | 150 | R. Overman, Esq.... | C 1853- |
| | " (Holkham) | 39 | J. Davidson, Esq.... | C 1848- |
| | " (") | 43 | " | 1860- |

NORTHAMPTONSHIRE.

| | | | | |
|---|--------------------------------------|------|-----------------------|-------------|
| | Brackley | 398 | Rev. B. F. Falkner | C 1864 T |
| | Kettering | ... | J. Wallis, Esq. | C 1863- |
| * | Northampton | ... | Mr. Ellick..... | C 1863- |
| | " (Althorpe House) | 310 | Mr. Jakeman | C 1841- |
| | " (") | ... | | 1827 |
| | " (Holdenby) | 385 | Rev. C. H. Hartshorne | C 1864- |
| | " (Yardley Hastings) | 180? | Rev. R. W. Prichard | C 1862- |
| * | Oundle | 124 | Mr. Ellick..... | C 1860-62 T |
| | " (Southwick) | ... | G. Lynne, Esq. | 1726-39 |
| † | Peterborough (Marholm) | ... | Rev. R. S. C. Blacker | C 1859-62 T |
| * | Potterspury [Stoney Stratford] | ... | Rev. R. E. Crawley | C 1865- |
| | Towcester (Blakesley) | ... | Rev. F. H. White... | C 1824-46 T |
| | Wansford (Kings Cliff) | ... | M. J. B. | |
| | Weedon Beck | ... | Rev. J. S. Winter... | C 1864- |
| | Wellingborough | ... | | 1840 imp. |
| | " | ... | M. Sharman, Esq.... | 1860- |

NORTHUMBERLAND.

| | | | | |
|--|--------------------------------------|------|-----------------------|-------------------|
| | Allenheads [Alston] | 1400 | Rev. W. Walton ... | 1841-43 |
| | " (") | 1369 | T. J. Bewick, Esq.... | C 1854- |
| | " (") | 1375 | " | C 1852- |
| | Alnwick (Glanton Pike) | 534 | F. Collingwood, Esq. | C 1862- |
| | " (High House) | 400 | Mr. Scott | C 1860- |
| | " (Howick) | 120 | Earl Grey | 1864- |
| | " (Roddam) | 545 | Mrs. Roddam | 1861- |
| | Bellingham (Hesleyside) | 420 | W. H. Charlton, Esq. | 1863- |
| | " (Otterbourn) | ... | Rev. T. Wearing ... | C 1865- |
| | Berwick (Cheswick) | 95 | J. D. Selby, Esq. ... | 1842, 1845-49 imp |
| | Bywell | 87 | Mr. Dawson | C 1855- |
| | Deadwater, 55° 17' N. 2° 38' W. | ... | Mr. Scott | 1862- |
| | Hexham (Bingfield) | 410? | Capt. Orde | C 1864- |
| | " (Newborough) | ... | Rev. H. Wastell ... | 1821-24 |
| | " (Ovingham) | ... | | |
| | " (Parkend) | 277 | M. A. Ridley, Esq. | 1846-52, 1860- |
| | Morpeth (Brenckburn Priory) | 200? | C. H. Cadogan, Esq. | 1864- |
| | " (Cresswell) | ... | B. Cresswell, Esq. | |
| | " (Widdrington) | ... | | 1722-23 imp. |
| | Newcastle-on-Tyne (O. S. O.) | 187 | Lieut. Sitwell | 1852, 1856-62 T |
| | " (Institution) | ... | W. Lyall, Esq. | C 1865- |
| | " (Stamfordham) | 400 | Rev. J. F. Bigge ... | C 1854- |
| | " (" Church) | ... | " | C 1865- |
| | " (West Denton) | 250 | G. C. Atkinson, Esq. | 1845-52 T |
| | " (Wylam) | 96 | " | C 1854- |
| | " (Camphill) | ... | D. D. Main, Esq. ... | 1864- |
| | " (Fawcett) | ... | " | 1864- |
| | " (Green Crag) | ... | " | 1864- |
| | " (Hallington) | 400 | " | 1864- |
| | " (Valley N. Tyne) | ... | " | 1864- |
| | " (Whittle Dean) | 380 | " | 1864- |
| | " (Woodford) | ... | " | 1864- |

NORTHUMBERLAND (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---|-------------------------------|------------|----------------------|---------|
| † | North Shields (Rosella Place) | 120 | R. Spence, Esq. ... | 1856-58 |
| | " (") | 124 | " | 1860- |
| | " (Low Lights) | 20 | J. R. Proctor, Esq. | C 1862- |
| | " (Tynemouth) | 61 | P. J. Messent, Esq. | 1864- |
| | " (Wallsend) ... | 100 | R. R. Deas, Esq. ... | 1863- |
| * | " (Whitley) ... | 83 | Rev. R. F. Wheeler | C 1864- |
| | Shotley | 309 | Mr. Routledge | 1859- |
| | Wooler (Lilburn Tower)..... | 290 | E. J. Collingwood... | 1860- |
| | " (Middleton Hall)..... | 240 | J. T. Leather, Esq. | 1864- |
| * | " (Millfield) | 200 | G. A. Grey, Esq. | C 1864- |

NOTTINGHAMSHIRE.

| | | | | |
|--|-------------------------|-----|-----------------------|-----------------|
| | Nottingham | ... | Nicholson's Journ. | 1808-10 |
| | " (Beeston Observatory) | ... | E. J. Lowe, Esq. | |
| | " (" Meadow) ... | 100 | Mr. W. Barker | C 1861- |
| | " (Bromley House)..... | ... | R. N. Harris, Esq.... | 1836, 1839 imp. |
| | " (Highfield ") ... | 162 | E. J. Lowe, Esq. ... | 1860- |
| | " (" ") ... | 184 | " | 1860- |
| | " (West Bridgeford) ... | ... | Nicholson's Journ. | 1808-09 |
| | Retford | 52 | M. S. & L. R. | C 1855- |
| | " (East) | 50 | J. S. Piercey, Esq. | 1860- |
| | " (West) | 50 | Rev. D. Butterfield | C 1858- |
| | Southwell | 200 | W. W. P. Clay, Esq. | C 1844- |
| | " (Oxton) | ... | H. Sherbrook, Esq. | 1862- |
| | Worksop | 127 | M. S. & L. R. | C 1855- |
| | " (Welbeck) | ... | Mr. Tillery | 1840- |

OXFORDSHIRE.

| | | | | |
|--------|--------------------------------|-----|-----------------------|------------------|
| | Banbury | 340 | J. Jarvis, Esq. | 1850-63 |
| | " (High Street) | 345 | T. Beesley, Esq. ... | C 1851-57, 1860- |
| | " | ... | W. Johnson, Esq.... | C 1861- |
| | " (Grimsbury)..... | 320 | T. Beesley, Esq. ... | 1862 imp. |
| | " (Neithrop) | 470 | " | 1862 |
| | Bicester | 220 | W. Johnson, Esq.... | C 1853-60 T |
| | " (Heyford Warren) ... | ... | Rev. C. B. Mount... | C 1865- |
| * B.A. | " (Stratton Audley) ... | ... | G. Glen, Esq. | C 1865- |
| * | Chipping Norton (Kingham) | ... | Rev. J. W. Lockwood | C 1865- |
| | Enstone (Radford) | 270 | Rev. E. W. Winter | C 1863- |
| | Henley-on-Thames | 83 | T. F. A. Byles, Esq. | C 1864- |
| | Oxford (Radcliffe Observatory) | 234 | Rev. R. Main | C 1815- |
| | " (" ") | 210 | " | 1851- |
| | " (" ") | ... | " | |
| | " (" ") | ... | " | |
| | " (Rosehill) | 270 | Rev. J. Slatter | C 1848-61 T |

RUTLANDSHIRE.

| | | | | |
|---|--------------------------|-----|----------------------|---------------------|
| † | Oakham (Empingham) | ... | Mr. Fancourt | 1828, 1833, 1836-41 |
| | " (Lyndon) | ... | T. Barker, Esq..... | 1844-61 |
| | " (Ryhall) | ... | Rev. C. Potchett ... | 1736-94 |
| | | | | 1865- |

SHROPSHIRE.

| | | | | |
|---|--|-----|--------------------|--------------|
| | Burford [Tenbury] | 180 | Lord Northwick ... | 1847- |
| | Church Stretton (Acton Scott) | ... | | 1852-53 imp. |
| | " " | ... | | 1852 imp. |
| | " " (Longnor)... | ... | | 1852 |
| * | " " (Woolstaston) | ... | Rev. D. Carr..... | C 1865- |
| | Cleobury Mortimer (Mawley Gardens) | ... | Mr. Hunter. | |

SHROPSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|--------|--|------------|----------------------|-------------|
| | Cleobury Mortimer (Mawley T. Farm) | 600 | Mr. Bourne | C 1862-64 T |
| | Ludlow (Knowbury) | 1000 | Rev. J. B. James ... | 1852- |
| | Oswestry (Hengoed) | 471 | Rev. A. R. Lloyd ... | 1856- |
| | " (Whittington) | ... | " | 1852 imp. |
| | Shifnal (Badger) | ... | Miss Elwell | 1863- |
| | " (Evelith) | 430 | Rev. J. Brooke | C 1847- |
| | " (Haughton Hall) | 450 | " | C 1835-46 T |
| | " (" Vicarage) | 400 ? | H. C. Marshall, Esq. | 1860- |
| | Shrewsbury | 192 | T. Howells, Esq. ... | 1860- |
| | " (Highfield) | 200 | Rev. B. Banning ... | C 1865- |
| * B.A. | Wellington | ... | Rev. J. E. Yeadon... | C 1864- |
| | Whitchurch | ... | | |

SOMERSETSHIRE.

| | | | | |
|---|------------------------------|-----|-----------------------|--------------|
| | Axbridge (Sidcot) | 250 | H. Dymond, Esq.... | C 1854- |
| | Barrow Gurney Reservoir ... | 310 | C. W. Bragge, Esq. | C 1855- |
| | Bath (Larkhall) | ... | | 1841-43 imp. |
| | " (Axford Buildings) | 150 | C. S. Barter, Esq.... | 1855-61 T |
| | " (Batheaston) | 226 | A. Mitchell, Esq. ... | 1862- |
| | " (Hospital) | 56 | C. S. Barter, Esq.... | C 1862- |
| | " (Swainswick) | ... | Rev. F. Lockey..... | C 1834- |
| | " (Literary Institution)... | ... | C. P. Russell, Esq. | C 1862- |
| | " (Weston) | 198 | | 1767-69 |
| | Bridgewater | ... | A. Haviland, Esq.... | 1860 T |
| | " | 45 | Dr. C. J. Fox | C 1848- |
| | Brislington [Bristol] | 181 | | 1855 imp. |
| | Burnham (Highbridge) | ... | Mr. Hull | C 1859- |
| | Chard (Tudbeer) | ... | | 1845-48 |
| | Frome (Beckington) | 265 | Mr. Raynes | 1852-62 |
| | " (Mells) | 300 | Rev. J. Horner | 1865- |
| | " " | ... | Mr. Boycott | C 1859-63 T |
| | " (North Hill) | ... | Mr. W. S. Clark ... | 1860-62 |
| | Glastonbury (Street) | 100 | Mr. J. Clark | 1861- |
| | " (") | 100 | C. W. Bragge, Esq. | C 1855- |
| | Harptree (Sherborne Reserv.) | 360 | J. W. Bourne, Esq.. | 1863- |
| | Ilchester | 30 | W. Blake, Esq..... | C 1864- |
| | Ilminster (South Petherton) | ... | R. Palmer, Esq. ... | C 1856- |
| | Langport (Long Sutton) | 150 | Mr. Atkins | 1782 |
| | Minehead | ... | | (1841) |
| | Radstock (Rectory) | 250 | Rev. T. B. Snow ... | 1863- |
| | " (Downside College) | 601 | | 1855 imp. |
| | Shepton Mallet (Doulting)... | ... | Rev. W. Tuckwell | C 1865- |
| | Taunton (College School) ... | ... | W. Reid, Esq. | C 1865- |
| * | " (Fulland's School) | ... | Dr. Gillett..... | C 1855- |
| | " (Paul's House) | 38 | F. H. Cator, Esq.... | C 1864- |
| * | " (Wey House) | 40 | Mr. Govett | 1831-58 |
| | Watchet (Kilton) | ... | W. Elworthy, Esq. | C 1865- |
| * | Wellington (Foxdown) | ... | Rev. T. J. Bumpstead | C 1863- |
| | Wells (Dinder) | 140 | Mr. Boycott | C 1863- |
| * | Weston-super-Mare | 8 | B. Boucher, Esq. ... | C 1864- |
| * | Wiveliscombe | ... | | |

STAFFORDSHIRE.

| | | | | |
|--|------------------------------|-----|----------------------|-------------|
| | Dudley (Abberley Street) ... | ... | H. B. Biden, Esq.... | C 1865- |
| | " (Brierley Hill) | 560 | " | C 1861-64 T |
| | Knypersley [Congleton] | 500 | J. Forbes, Esq. | 1863- |
| | Leek (Church Lane) | 591 | Mr. Farrow | 1856- |

STAFFORDSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|--|--------------------------------|------------|------------------------------------|---------|
| | Leek (Rudyard) | 500 | J. Forbes, Esq. | 1863- |
| | Oakmoor (Ellastone) | 350 ? | Rev. Sir C. P. Lighton, Bart | C 1864- |
| | Stoke-upon-Trent | ... | Dr. Garner | |
| | " (Etruria)... | 440 | J. Forbes, Esq. | 1863- |
| | " (Stanley)... | 550 | " | 1863- |
| | Uttoxeter (High Wood) | ... | J. F. Bell, Esq. | 1864- |
| | Wincle [Macclesfield] | 500 | J. Forbes, Esq. | 1864- |
| | Wolverhampton (Oaklands) | 470 | H. Ward, Esq. | 1860- |
| | " (Goldthorne Hill) | 521 | W. H. Ford, Esq. | 1863- |
| | " (Chillington) | ... | T. W. Gifford, Esq. | |
| | " (Patshull) | 400 | Rev. B. S. Malden | 1864- |
| | " (Wrottesley Observ.) | 531 | Lord Wrottesley ... | 1858 |
| | " (" mean of | | | |
| | two gauges) | 531 | " | 1859- |
| | " (" Osler's gau.) | 553 | " | 1843- |

SUFFOLK.

| | | | | |
|---|---------------------------------|-----|-------------------------|---------------|
| | Brome [Diss] | ... | Lady Bayning | 1843-47 imp. |
| | Bury St. Edmunds— | | | |
| † | " (Abbeygate St.)... | ... | E. Skepper, Esq. ... | C 1860- |
| † | " (Beech Hill)..... | ... | H. Turner, Esq. ... | C 1861- |
| † | " (Barton Hall) ... | ... | Mr. Allan | C 1859- |
| † | " (Botanic Gardens) .. | ... | E. Skepper, Esq. ... | C 1863- |
| † | " (Culford) | ... | Mr. Grieve | C 1858- |
| | " (Fornham Hall).. | ... | Mr. Halliday | 1847 |
| † | " (Thurston Lodge) .. | ... | Rev. W. Steggall ... | 1834, 1860-63 |
| † | " (Nether Hall) ... | ... | W. C. Bassett, Esq. ... | C 1860-63 T |
| † | " (Westley) | ... | R. Burrell, Esq. ... | 1860- |
| | Eye (Yaxley) | ... | Rev. W. H. Sewell .. | 1865- |
| | Hadleigh (Aldham) | ... | Rev. J. H. Lloyd ... | 1851- |
| | Ipswich (Grundisburgh) | ... | P. Harris, Esq. | C 1860- |
| | Lowestoft (Carlton Colville) .. | 8 | G. Edwards, Esq. | 1864- |
| | " | ... | Sir F. Crossley | (1865) |
| | " (Gisleham) | ... | Rev. J. Jodrell | 1862- |
| | " (Burgh Castle) ... | 10 | C. Cory, Esq. | C 1858-64 T |
| | " (Hopton Hall) ... | 70 | " | C 1864- |
| | Mendlesham (Thwaite) | ... | Mr. Whistlecraft ... | 1830- |

SURREY.

| | | | | |
|---|-----------------------------|-----|----------------------------|-----------|
| | Bagshot | 430 | Dr. Blount | 1860- |
| | " (Duke's Hill) | ... | H. J. B. Hancock, Esq. ... | C 1865- |
| | " (Park) | 230 | Sir J. Clark, Bart. | C 1864- |
| | " (Windlesham) | 205 | G. Dines, Esq. | C 1864- |
| | Battersea | 13 | J. B. Faunthorpe, Esq. ... | C 1856- |
| | Betchworth (Brockham) | 130 | W. Bennett, Esq. | 1860- |
| | " (The Holmes) ... | 300 | E. T. Bennett, Esq. ... | C 1861-63 |
| | " (Buckland) | ... | Rev. W. F. Hotham .. | |
| * | Brixton Hill | ... | Miss Sweeting | C 1865- |
| | Caterham | 370 | Dr. Westall | 1862-63 |
| | Clapham (Cedars Road) | ... | H. Doxat, Esq. | 1859- |
| † | Cobham Lodge | 100 | Miss Molesworth ... | C 1824- |
| | Croydon | ... | Dr. Westall | 1860- |
| | " (Waddon House)... | ... | S. Courtauld, Esq. ... | C 1865 T |
| | Dorking (Box Hill) | 500 | E. Boorman, Esq. | C 1864- |
| | " (Bury Hill) | 377 | A. K. Barclay, Esq. ... | 1852-59 |
| | " (Deepdene) | ... | Mr. Whiting | 1851- |
| | " (Denbies) | 600 | Mr. Drewett | 1861 |
| | " (Kitlands) | 580 | D. D. Heath, Esq. ... | C 1852- |

SURREY (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---|-----------------------------------|------------|-----------------------|-------------|
| † | Godalming (Dunsfold) | ... | W. L. Woods, Esq. | 1861- |
| | " (Wonersh) | ... | " | 1860 T |
| | Kew Observatory | 19 | B. Stewart, Esq. ... | C 1856- |
| | Kingston | ... | T. Chalk, Esq. | |
| | Reigate. | | | |
| | " | ... | Dr. Martin. | |
| | " (Ham, Red Hill) | ... | J. G. Marriage, Esq. | 1860-63 |
| | St. Thomas' Hospital | ... | Dr. Thomson. | |
| | South Lambeth | ... | | 1782-92 |
| | Wandsworth (St. Ann's Hill) | 70 | G. Dines, Esq. | C 1858-64 T |
| | " (South Fields) | ... | R. Coleman, Esq. | C 1861- |
| | Weybridge (Heath Bartrop) | 120 | W. F. Harrison, Esq. | C 1856- |

SUSSEX.

| | | | | |
|--|-------------------------------|-----|------------------------|------------------------------|
| | Arundel (Dale Park) | 316 | J. C. Fletcher, Esq. | 1846-52, 1860- |
| | " (Slindon) | 195 | Rev. M. Smelt | 1860-63 |
| | Bognor (Aldwick) | 12 | H. Upton, Esq. | C 1860- |
| | " (") | 22 | " | C 1863 |
| | " (Bersted Lodge) | 9 | J. Graham, Esq. ... | C 1845-52 T |
| | Brighton | 200 | J. A. Hingeston, Esq. | 1855-57 |
| | " | ... | Mr. Mossop | 1790 |
| | " (Upper Brunswick Pl.) | 50 | Dr. Kebbel | C 1859- |
| | Chichester | ... | Nicholson's Journ. | 1808-10 |
| | " (Museum) | 20 | W. Hills, Esq. | C 1835- |
| | " (West Gate) | 12 | Dr. Tyacke | 1854- |
| | " (Chilgrove) | 284 | W. L. Woods, Esq. | C 1834- |
| | " (Bepton Hill) | 554 | " | C 1864- |
| | " (Funtington) | 70 | G. M. Fort, Esq. ... | 1860-63 |
| | " (Shopwyke) | 61 | Rev. G. H. Woods. | C 1850- |
| | " (Westbourne) | ... | | 1842-43 |
| | " (West Dean) | 260 | H. Paxton, Esq. ... | C 1845- |
| | " (") | 250 | Rev. G. H. Woods | C 1834-49 T |
| | " (West Thorney) ... | 10 | F. Padwick, Esq. ... | 1860- |
| | Crawley (The Hyde) | 300 | E. S. Bigg, Esq. ... | C 1856- |
| | Cuckfield (Balcombe Place) .. | 340 | J. A. Hankey, Esq. | C 1862- |
| | Eridge Castle | ... | | 1863- |
| | * Forest Row | ... | T. Dyke, Esq. | C 1865 |
| | Frant | ... | Dr. Allnatt. | |
| | Hastings | ... | | (1838) |
| | " | ... | — Phillips, Esq. ... | (1842-46) |
| | " (Battle) | ... | F. Webster, Esq. ... | C 1861- |
| | † " (Bleak House) | 80 | Mr. Banks | C 1846- |
| | † " (Cemetery) | 450 | Mr. Field | 1862 |
| | † " (Fairlight) | 500 | J. Rock, Esq. | C 1857-63 T |
| | " (High Street) | 60 | J. A. Langham, Esq. | 1861 T, imp. |
| | " (High Wickham) ... | 212 | E. Field, Esq. | C 1859- |
| | † " (St. Leonard's Marina) .. | 10 | J. C. Savery, Esq. ... | 1860-62 |
| | † " (" 39 Tower) ... | 10 | " | 1860-62 |
| | * " (Otley House) | ... | J. Rock, Esq. | C 1865- |
| | Hurstpierpoint | 120 | Rev. J. Gorham ... | C 1860- |
| | Lewes (Glynde) | 45 | J. Macleod, Esq. ... | 1856-57 1859,
1860, 1863- |
| | " (Landport Cottage) ... | ... | Mr. W. Smith | 1852 |
| | Petworth Rectory | ... | Rev. C. Holland ... | C 1862- |
| | Pevensey | ... | Major Vidler. | |
| | Robertsbridge (Salehurst) ... | ... | Mr. S. Boorman ... | C 1864- |
| | Rogate (Fair Oak) | 245 | Hon. I. J. Carnegie | 1860-63 |
| | Uckfield | 200 | C. L. Prince, Esq. ... | 1850, 1852, 1856- |
| | " (Maresfield Forest Lod.) | 301 | Capt. W. Noble ... | C 1856- |

SUSSEX (continued).

| | Station. | Elevation. | Observer. | Period. |
|--|-------------------------------|------------|---------------------|----------------|
| | Uckfield (Maresfield Rectory) | 250 | Rev. E. Turner..... | 1859- |
| | " (Buxted Park) | 200 | | 1856-57, 1859- |
| | " (Moulsey Gore) | ... | F. Brodie, Esq..... | C 1863- |
| | " (Newick, Beechland).. | ... | | 1862- |
| | " (" Ketches) ... | ... | Miss Shiffner | C 1865- |
| | Worthing | 12 | Dr. Barker | 1853-61 |
| | " (Findon) | 150 | Rev. Dr. Cholmeley | C 1864- |

WARWICKSHIRE.

| | | | | |
|---|-------------------------------|-----|-----------------------|--------------|
| | Birmingham (Phil. Institute). | 490 | Dr. Ick | 1836-45 imp. |
| † | " (Midland ") | 557 | C.J. Woodward, Esq. | 1862 |
| † | " (Bloomsbury St.) | 340 | D. Smith, Esq. | C 1861- |
| | " (Camp Hill) ... | 425 | T. L. Plant, Esq. ... | C 1853-63 T |
| † | " (Edgbaston) ... | 510 | W. Southall, Esq.... | C 1855- |
| | " (Moseley) | 481 | T. L. Plant, Esq. ... | C 1864- |
| | " (Wellington Rd.) | 450 | T. Southall, Esq. ... | C 1853-60 T |
| * | Coventry (Walsgrave-on-Sour) | ... | Rev. H. H. Pinniger | C 1865- |
| * | Henley-in-Arden | ... | G. R. Dartnell, Esq. | C 1865- |
| | Leamington (Upper Parade) | 195 | S. U. Jones, Esq. ... | C 1862- |
| | " (Stoneleigh Abbey) | .. | Mr. T. Bowick | 1858-62 T |
| | Rugby | 315 | F. Fuller, Esq. | C 1854- |

WESTMORELAND.

| | | | | |
|---|------------------------------|------|-----------------------|---------------|
| † | Ambleside (Lesketh How) ... | 200 | Dr. J. Davy | 1844, 1848- |
| | " (Lough Rigg)..... | 580 | E. B. W. Balme, Esq. | 1863- |
| | " (Low Nook) | 150 | J. C. Wilson, Esq.... | C 1859- |
| | Appleby | 242 | Dr. Armstrong | C 1856- |
| | Bowness. | | | |
| | " (Craig)..... | ... | Adm. Sir T. S. Pasley | 1847-52 imp. |
| | " (Craigfoot). | | | |
| | Brougham Hall [Penrith] ... | 516 | W. Brougham, Esq. | 1852 |
| | Eusemere Hill [Penrith]..... | 360 | Mrs. Angas | C 1863-64 T |
| | Grasmere | 240 | J. Green, Esq. | 1862 |
| | " (Lancregg) | 300 | Sir J. Richardson... | C 1859-61 T |
| | Great Strickland [Penrith].. | 700 | H. H. Plumer, Esq. | C 1864- |
| | Halsteads [Penrith]..... | ... | W. Marshall, Esq. .. | 1820-33, 1863 |
| | Kendal | ... | Dr. Dalton | C 1788-92 T |
| | " | ... | Nicholson's Journal | 1808. |
| † | " | 149 | S. Marshall, Esq. ... | C 1809- |
| | " | ... | J. Gough, Esq. | 1787-99 imp. |
| | " (Benson Knott) | ... | | 1790-91 imp. |
| | " (Selside) | 736 | | 1849-53 |
| | " (" Low Bridge House). | | | |
| | " (Waith Sutton) | ... | Manchester Memoirs | 1789-93 |
| | Kirkby Lonsdale | 209 | W. Harrison, Esq. . | C 1863- |
| | " (Vicarage)..... | 210 | Rev. H. Ware | C 1864- |
| | " (Biggins House). | 400? | A. B. Tomlinson, Esq. | 1864- |
| | " (Dalton Hall) ... | ... | E. G. Hornby, Esq.. | C 1864- |
| | " (Rigmaden) | 155 | E. Wilson, Esq. ... | C 1864- |
| | " (Whelprigg)..... | ... | Mrs. Gibson. | |
| * | " Stephen | ... | T. Mason, Esq..... | C 1865- |
| | Lowther Castle [Penrith] ... | 840 | J. Parkes, Esq., C.E. | 1860, 1863- |
| | Milnthorpe (Sedgwick) | ... | J. Wakefield, Esq.... | Imp. |
| | Patterdale | 500 | Mr. Sinclair | 1863- |
| | Troutbeck (The How) | 470 | J. Wilson, Esq..... | 1844- |

1865.

R

WILTSHIRE.

| | Station. | Elevation. | Observer. | Period. |
|----|------------------------------------|------------|--------------------------|-------------|
| † | Calne (Castle House) | 282 | Col. Ward | C 1861- |
| *† | " ("), Experimental gauges | ... | ... | Various. |
| | Chippenham (Badminton) ... | ... | Mr. J. Trotter | C 1861- |
| | Devizes (Gore, Lavington) ... | ... | F. Stratton, Esq. ... | C 1865- |
| | Heytesbury (Chiltern)..... | 200 | Mr. R. Hayward, Jun. ... | 1864- |
| | Marlborough | 500 | W. C. Merriman, Esq. ... | C 1861- |
| | " (College) | 456 | Rev. T. A. Preston . | C 1864- |
| | Salisbury (Alderbury) | ... | G. Fort, Esq. | 1860-63 |
| | " (Baverstock) | 300 | Archdeacon Hony ... | C 1830- |
| | " (Woodford) | ... | H. Hinxman, Esq. ... | C 1862-63 |
| | Swindon (Highworth)..... | 435 | E. E. Dymond, Esq. ... | C 1865- |
| | Trowbridge (Holbrook Farm) .. | ... | Mr. Fryer | 1861- |
| | " | ... | W. J. Mann, Esq. ... | ... |
| | " (Winkfield) | ... | Mr. Boycott | C 1858-59 T |
| | Warminster | ... | Rev. W. Slatter | C 1857-59 T |
| | " (Chapmanslade) | ... | F. Singer, Esq. | 1855-60 |
| | " (Longbridge Deveril) | 400 ? | Rev. W. Slatter..... | C 1860- |

WORCESTERSHIRE.

| | | | | |
|--|---|-----|-------------------------|---------|
| | Kidderminster (Spring Bank) .. | ... | Rev. C. Trotter. | |
| | Malvern, Great. | 500 | Dr. Williams | 1862- |
| | " West | 900 | H. Hartland, Esq. ... | C 1861 |
| | Northwick Park [Moreton-in-Marsh] | ... | Lord Northwick ... | 1859- |
| | Stourbridge | ... | R. Leach, Esq. | ... |
| | Tenbury (Brockleton) | ... | Rev. J. Miller | 1850-52 |
| | " (Orleton) | 200 | T. H. Davis, Esq. ... | C 1831- |
| | Worcester (Gas Office) | ... | F. N. Gosling, Esq. ... | C 1865- |
| | " (Railway Offices) .. | 125 | E. Wilson, Esq. ... | C 1858- |
| | " (" ") .. | ... | N. Edis, Esq. | 1855-56 |
| | " (Lark Hill) | 157 | W. Burgess, Esq. ... | C 1854- |
| | " (Belmont House) .. | ... | T. M. Hopkins, Esq. ... | ... |

YORKSHIRE, EAST RIDING.

| | | | | |
|--------|--|-----|--------------------------|-------------|
| | Driffield (Middleton) | ... | | 1834 imp. |
| † | " (") | 150 | Rev. H. D. Blanchard | 1843- |
| * | " (Nafferton Lodge)... | 87 | W. C. Laybourn, Esq. ... | C 1864- |
| *B. A. | Filey | ... | D. Philliskirk, Esq. ... | C 1865- |
| | Hull (Baker Street) | 10 | A. O. Atkinson, Esq. ... | C 1864- |
| † | " (Beverley Road) .. | 12 | J. Smith, Jun., Esq. ... | C 1857- |
| † | " (Manor House Street)... | ... | W. Lawton, Esq. ... | C 1849- |
| | " (Tranby Park, Hessle) .. | ... | F. Hoare, Esq. | 1863 |
| | " (Roos, Hedon) | ... | Phillips' Yorkshire . | 1834 |
| † | Market Weighton (Holme-on-Spalding Moor) | 32 | G. Dunn, Esq. | C 1860- |
| † | Pattingham | 32 | W. B. Pugh, Esq. ... | C 1846- |
| | " (Keyingham) | ... | M. Harrison, Esq. ... | ... |
| † | Pocklington (Huggate) | ... | Rev. T. Rankin | 1842-63 T |
| † | Wheldrake [York] | 36 | Rev. R. B. Cooke ... | C 1844-65 T |
| | " (Thicket Priory) .. | 26 | Miss M. D. Jefferson | C 1865- |

YORKSHIRE, NORTH RIDING.

| | | | | |
|---|------------------------------|-----|-------------------------|-------------|
| | Helmsley (Beadlam Grange) .. | 200 | J. H. Phillips, Esq. .. | 1856, 1862- |
| | Leyburn | 650 | G. M. Wray, Esq. ... | C 1863- |
| † | Malton | 73 | H. Hurtley, Esq. ... | C 1859- |
| | " | ... | ... | ... |

YORKSHIRE, NORTH RIDING (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|-------|-------------------------|------------|------------------------|---------------------------|
| | Malton (Brandsby) | ... | F. Cholmelly, Esq. . | 1834 imp. |
| | Middlesborough | ... | G. Turnbull, Esq. ... | 1841-42 |
| | " | 21 | W. Fallows, Esq. ... | C 1864- |
| | " (Marton Hall) | 120 | W. F. Bolcklow, Esq. | 1864- |
| *B.A. | Northallerton | ... | W. T. Jefferson, Esq. | C 1864- |
| | Richmond (Aske) | 550 | Earl of Zetland | 1842- |
| | Scarborough | ... | | 1832-41, 1844-46,
1849 |
| † | " | 91 | Dr. Hickson | 1860- |
| | Redcar | 20 | C. C. Oxley, Esq. ... | 1859- |
| | " (Upleatham) | 330 | Earl of Zetland | 1863- |
| *B.A. | Whitby | 184 | Mr. Simpson | C 1864- |
| *B.A. | " (Port Mulgrave) | 350? | A. S. Palmer, Esq. ... | C 1865- |

YORKSHIRE, WEST RIDING.

| | | | | |
|---|---------------------------------|------|------------------------|------------------|
| | Barnsley (Felkirk) | ... | Rev. J. B. Graham . | 1841 imp. |
| | Blackstone Edge [Todmorden] | | | |
| | " (Whiteholme) | 1500 | Manchester Memoirs | 1819-40, 1845-47 |
| | " (" Soc. gau.) | 1200 | " | 1844-47 |
| | " (Toll Bar) | 1000 | " | 1831-40, 1845-47 |
| | " (" Soc. gau.) | 1000 | " | 1844-47 |
| | Bolton-by-Bolland [Clitheroe] | ... | Rev. T. Staniforth... | 1834 |
| | Bradford (Mechanics' Inst.) .. | 370 | C. Lund, Esq. | C 1862- |
| † | " (Chellow Dean) .. | 634 | C. Gott, Esq. | C 1852- |
| * | " (Horton Hall) | 496 | Mr. G. Abbey | 1850-63- |
| | " (Queensbury) | ... | W. Foster, Esq. ... | C 1865- |
| | " (Queensgate) | 389 | J. M'Landesborough | 1863- |
| | Dewsbury (Mirfield) | 320 | E. B. W. Balme, Esq. | 1863- |
| * | Doncaster (Magdalens) | ... | Mr. J. Howorth | C 1864- |
| | " | ... | | 1853 imp. |
| | " (Cantley) | 30 | J. W. Childers, Esq. | C 1860- |
| | " (Owston) | ... | — Cooke, Esq. | 1852 |
| | Goole | ... | T. Kendall, Esq. ... | 1863- |
| | Halifax (Dean Clough Mills) | 475 | L. J. Crossley, Esq. . | C 1865- |
| | " (Hunter's Hill) | 1300 | G. W. Stevenson, Esq. | C 1852-61 T |
| | " (Midgeley Moor) .. | 1350 | " | C 1856- |
| | " (Ovendon Moor) .. | 1375 | " | C 1852- |
| | " (Ripponden, Blk. Hou.) .. | ... | Manchester Memoirs | 1832-40, 1845-47 |
| | " (" Soc. gau.) | ... | " | 1844-47 |
| | " (South Owsram) | 880 | R. Richardson, Esq. | 1862- " |
| | " (Sowerby Bridge) .. | 268 | Manchester Memoirs | 1828-40, 1845-47 |
| | " (" Soc. gau.) | 300 | " | 1844-47 |
| | " (Warley Moor) | 1425 | G. W. Stevenson, Esq. | C 1853- |
| † | " (Well Head) | 487 | J. Waterhouse, Esq. | C 1829- |
| † | Harrogate | 420 | Dr. Bainbridge | C 1861- |
| | High Flats. | | | |
| | Holmfirth (Bilberry Reservoirs) | 800 | J. F. Bateman, Esq. | 1859-60, 1862- |
| | " (Boshaw Whams) .. | 950 | " | 1859, 1863- |
| | " (Holme Styes) | 850 | " | 1859-60, 1862- |
| | Huddersfield (Longwood) .. | 600 | C. Hare, Esq. | C 1859- |
| | " (Rastrick) | 410 | A. Clay, Esq. | C 1858- |
| | Ingleton (Clapham) | 550 | W. T. Walker, Esq. | 1852-63 |
| | Keighley (Braithwaite) | 780 | A. Shackleton, Esq. . | 1863- |
| | Leeds | ... | | 1845 imp. |
| | " (Barrowby) | ... | G. Lloyd, Esq. | 1772-81 |
| | " (Eccup) | 340 | E. Filiter, Esq. | 1844- |
| | " (Harewood Bridge) ... | 108 | H. Roberson, Esq. ... | C 1864- |
| | " (Headingley) | ... | H. C. Marshall, Esq. | 1820-37 |
| † | " (Holbeck) | 127 | " | 1842- |

YORKSHIRE, WEST RIDING (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|---|------------------------------|------------|------------------------|---------------------|
| † | Leeds (Holbeck Manor Road) | 95 | E. Filliter, Esq..... | 1849- |
| | " (Leventhorpe Hall) ... | 90 | J. T. Leather, Esq. .. | 1855- |
| † | " (Philosophical Hall)... | 137 | H. Denny, Esq..... | C 1823-63 |
| | " (Red Hall)..... | 452 | F. W. Stow, Esq. ... | C 1857-62 T |
| | " (Wind Hill) | 238 | W. Peel, Esq. | 1861-62 |
| | Otley..... | 206 | H. Thorns, Esq. | C 1860- |
| | " (Ben Rhydding) | 500 | R. C. Taylor, Esq.... | 1860-62 |
| | " (Chevin)..... | 764 | Mr. Lawson | C 1861-63 |
| | " (Ilkley) | ... | Dr. Scott | 1865- |
| | Peniston | 717 | M. S. & L. R..... | 1850-55 imp., 1859- |
| | " (Calcoates)..... | 1075 | " | 1860- |
| | " (Dunford Bridge)... | 954 | " | 1852-57 imp., 1859- |
| | Pontefract (Ackworth Moor- | ... | J. Brown, Esq. | |
| | top) | ... | Mr. A. Wright | 1854-57 |
| | " (" School) | 135 | Luke Howard, Esq. . | { C 1842-53 T |
| | " (" Villa). | 135 | | { C 1858-63 T |
| | " (Ferrybridge)..... | 30 | | 1842-46 |
| * | " (Kirk Smeaton) | ... | C. O. F. Cator, Esq. | 1864- |
| * | Ripon | ... | Dr. Frankland | C 1865- |
| | " | ... | F. W. Stow, Esq. ... | C 1864- |
| | Rotherham— | | | |
| | " (Wath-upon-Deerne) | 186 | W. M. Burman, Esq. | 1862- |
| | " (West Melton) | 172 | Rev. J. Boyd | C 1861- |
| | Saddleworth (Station) | 640 | E. Greenwood, Esq. | 1853- |
| | " (Friesland)..... | 540? | Rev. G. Venables ... | C 1864- |
| | " (Standedge) | 1150 | E. Greenwood, Esq. | 1850- |
| | Sedbergh (Garsdale)..... | ... | Mr. Blades | 1777-79 |
| | Settle | 498 | J. Tatham, Esq..... | C 1837- |
| | " (Arncliffe) | 750 | Rev. W. Boyd | 1853- |
| | " (Coniston) | ... | Rev. J. Stansfeld. | |
| | Sheffield | ... | W. J. Simmonite, Esq. | |
| | " (Broomhall Park)... | 337 | D. Doncaster, Esq. . | 1853- |
| | " (Crookesmoorside) . | 600 | " | 1864- |
| | " (Doncaster Street) .. | 170 | " | 1864- |
| | " (The Edge) | 336 | M. S. & L. R..... | C 1860- |
| | " (Redmires) | 1100 | J. Gunson, Esq. ... | C 1836- |
| | " (Station) | 188 | M. S. & L. R..... | 1850, 1855-57 imp. |
| | | | | 1858- |
| | Skipton | 430 | R. H. Sidgewick, Esq. | C 1863- |
| | " (Woodlands) | ... | J. Heelis, Esq. | |
| | Stansfield Hall [Todmorden]. | 500 | J. Fielden, Esq..... | 1864- |
| | Stubbins [Todmorden] | 364 | Manchester Memoirs | 1825-40 |
| | Tadcaster (Boston Spa) | 74 | F. R. Carroll, Esq.... | 1853- |
| | Thornton-in-Craven | 456 | T. Wilson, Esq..... | C 1863- |
| | Tickhill | 61 | Dr. Dixon | C 1859- |
| † | Wakefield (Prison) | 115 | W. R. Milner, Esq. . | 1848- |
| | " (The Heath) | ... | Nicholson's Journal | 1808-10 |
| † | York (Bootham) | 50 | J. Ford, Esq..... | 1831- |
| | " (Coney Street)..... | 40 | Mr. Sigsworth | C 1864- |
| | " (Museum) | ... | Prof. Phillips. | |
| | " (Minster roof) | ... | " | |

WALES.

ANGLESEA.

| | | | | |
|---|-----------------------------|-----|-----------------------|-----------|
| | Beaumaris (Henllys) | 150 | Miss Hampton | C 1864- |
| | Llandfrydog | 92 | H. Webster, Esq. ... | C 1860-63 |
| * | Llanfairynghornwy | ... | I. Williams, Esq. ... | C 1865- |
| | Menaifron [Carnarvon] | ... | Rev. W. W. Williams | C 1865- |

BRECKNOCKSHIRE.

| | Station. | Elevation. | Observer. | Period. |
|--|------------------------------|------------|---------------------|---------|
| | Crickhowell (Buckland) | ... | Mrs. G. Holford ... | 1861- |
| | Hay (Pen-y-Maes) | ... | Capt. Brown | 1860- |

CARDIGANSHIRE.

| | | | | |
|-------|-------------------|-----|---------------------|---------|
| *B.A. | Aberystwith | 12 | T. Paul, Esq..... | C 1864- |
| | Cardigan | 18 | G. B. Osborne, Esq. | C 1864- |
| | " | ... | Miss Parry. | |
| | Frongoch | 855 | H. Thomas, Esq. ... | 1863- |
| | Goginan | 290 | " | 1863- |
| | Lampeter | 420 | Rev. J. Mathews ... | 1855- |

CARMARTHENSHIRE.

| | | | | |
|-------|-------------------------------|-----|------------------------|-----------|
| * | Carmarthen | 70 | J. Rowlands, Esq.... | C 1864- |
| | " (Gaol) | 78 | G. Stephens, Esq. ... | C 1863- |
| *B.A. | " (Plas-cwrt-hyr)... | 150 | W. E. Gwyn, Esq.... | C 1864- |
| | Llandissillio (Rhydwen) | 150 | H. S. Morgan, Esq. . | 1859- |
| * | Llanelly | 20 | E. Bagot, Esq. | C 1864- |
| | " (Bridge Parade) | ... | J. H. Jenkins, Esq. . | 1842 imp. |
| * | " (Pont Amman) | ... | E. S. Morris, Esq. ... | C 1865- |

CARNARVONSHIRE.

| | | | | |
|-------|---------------------------------|------|------------------------|---------|
| † | Bangor | 105 | Rev. J. H. Purvis ... | 1861- |
| † | " (Llanfairfechan) | 140 | R. Luck, Esq. | C 1864- |
| | " (Llanllechid) | ... | Rev. J. Evans | C 1865- |
| *† | Beddgelert (Sygun) | 330 | Mr. T. Searell | C 1864- |
| * | Bethesda (Brynderwen) | 500 | J. Francis, Esq..... | C 1864- |
| * | " (Penrhyn) | 1200 | " | C 1864- |
| * | Bettws-y-coed | 70 | Rev. I. W. Griffith .. | C 1864- |
| | " (Minvie) | ... | Capt. W. D. Lowe... | (1865) |
| * | Carnarvon (Plas Brereton) ... | 85 | T. Turner, Esq..... | C 1864- |
| | Hendre | 90 | F. Ball, Esq. | C 1864- |
| * | Llanberis (Dinorwic Quarry). .. | 850 | G. Ellis, Esq..... | C 1864- |
| * | " (Glyn Padarn) ... | 377 | W. W. Craig, Esq. .. | C 1864- |
| *† | " (Roy. Vic. Hotel)... | 320 | Mr. Williams | C 1864- |
| * | Llangybi (Cefn) | 200 | Rev. S. G. A. Williams | C 1864- |
| * | Llanllyfni (Cilgwyn) | 500 | W. Hayward, Esq. .. | C 1864- |
| * | Llanystyndwy (Talarvor) ... | 50 | Dr. Roberts | C 1864- |
| * | Port Madoc | 30 | Capt. Mathew | C 1864- |
| *B.A. | Pwllheli | ... | J. T. Evans, Esq. ... | C 1865- |
| | Sarn (Aberdaron)..... | 340 | Mr. Jones | C 1863- |

DENBIGHSHIRE.

| | | | | |
|---|------------------------------|-----|-------------------------|---------|
| * | Denbigh (Plas Clough) | ... | J. H. S. Harrison, Esq. | C 1865- |
| † | Llandudno (Warwick House) .. | 80 | Dr. Nicol | C 1859- |
| | Wrexham (Gwersyllt Hill)... | 350 | W. Lassell, Jun., Esq. | C 1863- |

FLINTSHIRE.

| | | | | |
|----|-----------------------------|-----|-----------------------|-------------|
| † | Hawarden | 260 | Dr. Moffatt | C 1850- |
| | Holywell (Maes-y-dre) | 400 | J. Williams, Esq. ... | 1858- |
| | Mold (Bryn Alyn) | ... | Rev. R. B. Cooke ... | C 1865- |
| | " (Gwynsanny) | ... | P. D. Cooke, Esq. ... | 1852 |
| | Rhyl | ... | Mr. E. Evans | C 1860-64 T |
| *† | " (Gas Works) | ... | " | C 1865- |

GLAMORGANSHIRE.

| | | | | |
|---|---------------------------|----|---------------------|---------|
| | Cardiff | 50 | Dr. Vachell | 1863- |
| * | Cowbridge (The Ham) | 55 | G. W. Nicholl, Esq. | C 1864- |

GLAMORGANSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|--|--|------------|-------------------------|--------------|
| | Merthyr-Tydvil (Trondyrhiew House) | 500 | E. W. Seale, Esq. ... | C 1863- |
| | Swansea (Wind Street) | ... | | 1844-45 |
| | " (Harbour Office) | ... | J. W. James, Esq.... | C 1862- |
| | " (Alltygrug) | 700 | J. Rogers, Esq. | 1852 |
| | " (Graigarw) | 356 | J. D. " Llewellyn, Esq. | 1852 |
| | " (Penllégare) | ... | D. Smith, Esq. | 1852 |
| | " (Yniscedwyn) | 276 | J. Rogers, Esq. | C 1852- |
| | " (Ystalyfera) | 368 | J. W. Gutch, Esq.... | 1836-39 imp. |
| | " | 52 | — Moggridge, Esq. | |
| | " | ... | | |

MERIONETHSHIRE.

| | | | | |
|--------|------------------------------|-----|----------------------|-------------|
| * B.A. | Bala | 43 | Capt. Mathew | C 1865- |
| | " (Llandderfell) | ... | W. Pamplin, Esq.... | C 1865- |
| | Corwen (Rhug) | ... | J. Wagstaffe, Esq. | |
| | Dolgelley | ... | | C 1865- |
| * B.A. | " (Brithdin) | 500 | J. Hill, Esq. | C 1864- |
| * | " (Llanelltyd) | 20 | H. Moon, Esq. | C 1861-62 T |
| * | Festiniog (Blaenyddol) | 600 | G. Carson, Esq. | C 1864- |
| * | Mäntwrog (Cäen-y-coed) | 15 | Rev. W. H. Trendel | C 1864- |
| * | Talgarth Hall [Machynlleth]. | 150 | C. F. Thruston, Esq. | C 1864- |
| | Towyn | 18 | Dr. Williams | C 1864- |
| * | Trawsfynedd | 700 | Mr. Jarrett ... | C 1864- |

MONTGOMERYSHIRE.

| | | | | |
|--------|-------------------------------|-----|-----------------------|-------------|
| * B.A. | Berriew (Henllys) | ... | Miss Williams | C 1864- |
| | Llanidloes (Broomcliff) | ... | T. F. Roberts, Esq. . | C 1865- |
| | Machynlleth | ... | Rev. J. Evans | C 1861-62 T |

PEMBROKESHIRE.

| | | | | |
|--------|----------------------------|-----|-----------------------|---------|
| | Haverford West | 60 | E. P. Phillips | 1849- |
| * | Kilgerran | ... | Rev. D. Evans | C 1865- |
| | Pembroke Dock | 30 | E. Chevalier, Esq.... | C 1860- |
| * B.A. | Tenby (Caldy Island) | ... | Mr. Fletcher | C 1865- |

RADNORSHIRE.

| | | | | |
|--------|---------------------------|-----|-------------------|---------|
| * B.A. | Presteign | ... | Capt. Haman | C 1865- |
| | Rhayader (Cefnfaes) | 880 | Mrs. Jones | C 1858- |

CHANNEL ISLANDS.

| | | | | |
|--|----------------------------|-----|-----------------------|---------|
| | Guernsey | ... | | 1847 |
| | " | 200 | Dr. Hoskins | 1843- |
| | Jersey | ... | Dr. King | 1850-56 |
| | " (Fort Regent) | ... | Serjeant Wiseman. | |
| | " (Gorey, Rockmount) | 90 | Capt. Thompson | 1864- |
| | " (Millbrook) | 45 | P. Langlois, Esq. ... | 1858- |
| | " (St. Heliers) | 50 | A. W. P. Smith, Esq. | 1864- |
| | " (St. Lawrence) | ... | G. Gibb, Esq. | |
| | " | ... | | 1848 |

THE ISLE OF MAN.

| | | | | |
|--|--------------------|-----|----------------------|-------------|
| | Balasalla | 100 | J. Burman, Esq. ... | C 1853-61 T |
| | Calf of Man | 325 | Bd. of North. Lights | C 1824- |
| | Point of Ayr | 27 | " | C 1822- |
| | Douglas Head | ... | R. Stewart, Esq. ... | 1824-30 |
| | | | Bd. of North. Lights | C 1860- |

SCOTLAND.

ABERDEENSHIRE.

| | Station. | Elevation. | Observer. | Period. |
|---|-----------------------------|------------|--------------------------|-----------------|
| | Aberdeen | ... | Aberdeen Herald ... | 1842 |
| | " | ... | T. D. Gray, Esq. ... | 1856-59 imp. |
| | " (Ashley Place) ... | 112 | Rev. A. Beverley ... | C 1864- |
| | " " | 115 | " | C 1864- |
| | " (Gordon Hospital) ... | ... | Mr. Innes | C 1837-41 |
| | " (Grammar School) ... | 103 | Rev. A. Beverley ... | C 1864- |
| | " " | 161 | " | C 1864- |
| | " (Marischall College) ... | ... | | 1829-37 T |
| | " (North Broadford) ... | 55 | Rev. A. Beverley ... | 1863 T |
| | " (Kemhill) | ... | Mr. W. Smith | C 1850-54, 1858 |
| † | " (Rose Street) | 100 | A. Cruickshank, Esq. ... | C 1860- |
| * | " (Wallfield) | 163 | R. Catto, Esq. | C 1864- |
| | Alford | 420 | Rev. J. Farquharson ... | 1835-42 |
| | " (Balfluig) | 420 | Dr. Gordon | 1843-48 |
| | Ballater | 656 | J. W. Paterson, Esq. ... | C 1861- |
| | " (Coldstone) | 680 | Mr. J. G. Michie .. | C 1863- |
| | Braemar | 1110 | Mr. J. Aitken | 1856- |
| | Ellon (Castle) | ... | Mr. Howitt | |
| | " (Tillydesk) | 360 | Mr. W. Hay | C 1861- |
| | Fraserburgh (Lonmay) ... | ... | Statistical Account .. | 1832 imp. |
| | Huntly Lodge | ... | | 1821-29 imp. |
| | Inverury (Manse) | 213 | Rev. J. Davidson ... | C 1862- |
| | " (Kenmay Manse) ... | 307 | Rev. G. Peter | 1863- |
| | " " | 300 | " | 1864- |
| | Kinnaird Head | 64? | Bd. of North. Lights ... | C 1813- |
| | New Pitsligo | 506 | Mr. D. Sturrock ... | C 1862- |
| | Old Deer (Manse) | 134 | Rev. J. Peter | 1863- |
| | Peterhead | ... | | 1808-10 imp. |
| | " (Buchanness) | 35? | Bd. of North. Lights ... | C 1827- |
| | Strathdon (Castle Newe) ... | 915 | Mr. A. Walker | C 1849- |
| | Tough (Tornaveen) | 713 | W. N. Fraser, Esq. ... | 1864- |

ARGYLLSHIRE.

| | | | | |
|-------|--|-----|--|------------------|
| | Ardnamurchan | 82? | Bd. of North. Lights ... | C 1849- |
| | " (Camusinas) | ... | A. Buchan, Esq. ... | 1864- |
| | Campbelltown (Devaar) | 75 | Bd. of North. Lights ... | C 1854- |
| | " (Southend) | ... | Statistical Account .. | 1831 |
| | Cantire (Mull of) | 279 | Bd. of North. Lights ... | C 1813- |
| | Dalmally (Bridge of Orchy) .. | 500 | A. E. M ^c Dougall, Esq. ... | 1864- |
| | " (Drishraig) | 250 | " | 1862- |
| | Dunoon (Castle Toward) ... | 80 | Mr. W. Milne | 1824- |
| | " (Hafton) | 40 | Mr. D. Doig | C 1853- |
| | " (Kirk, Oak Bank) | ... | J. Richardson, Esq. ... | C 1865- |
| *B.A. | Fort William (Rosse Parsonage) .. | ... | Rev. W. Simpson ... | C 1865- |
| | Inverary Castle | 30 | Mr. J. Caie | 1833, 1860- |
| | " (Glenary) | 300 | Statistical Account .. | 1834, 1835 |
| | Islay (Rhinn's of) | 74 | Bd. of North. Lights ... | C 1826- |
| | " (M ^c Arthur's Head) | 106 | " | C 1861- |
| | " (Rhu Vaal) | ... | " | C 1859- |
| | Jura Sound (Fladda) | 20 | " | C 1860- |
| | Lismore (Mousedale) | 37 | | C 1833-45, 1848- |
| | Loch Eil (Ardgour) | 60 | A. Maclean, Esq. ... | 1862-63 imp. |
| | " (Corran) | 14 | Bd. of North. Lights ... | C 1860- |
| | Lochgilphead (Ballimore) ... | ... | Statistical Account .. | 1833-40, 1842-55 |
| | " (Calton Môr) | 65 | Mr. J. Russell | C 1855- imp. |
| | " (Kilmartin) | 64 | Mr. H. Gillies | 1861-62, 1864 |
| | " (Kilmory) | 100 | Sir J. P. Orde, Bart. ... | 1835-37, 1849- |

CAITHNESS (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|-------|-----------------------|------------|-----------------------|---------|
| *B.A. | Thurso | ... | Mr. Cowper | C 1865- |
| | " (Holburnhead) | 60? | Bd. of North. Lights | C 1862- |
| | Wick | ... | Statistical Account.. | 1840 |
| | " (Noss Head) | 127? | Bd. of North. Lights | C 1849- |

CLACKMANNANSHIRE.

| | | | |
|--------------------------|-----|--------------------|------------------|
| Alloa | 67 | Dr. McGowan | 1856 |
| " (Craigwood Cottage) .. | 20 | Mr. Bald | C 1838-53 T |
| Dollar Academy | 170 | Mr. Westwood | C 1839-58, 1862- |

DUMBARTONSHIRE.

| | | | |
|------------------------------|-----|------------------------------------|--------------|
| Dumbarton (Cardross) | 50 | J. W. Burns, Esq. | 1864- |
| Gareloch (Row) | 75 | G. S. Thomson, Esq. | 1857 imp. |
| Kirkintilloch | ... | | 1781-88 imp. |
| Loch Lomond (Ardvoirlich I.) | 50 | A. E. M ^c Dougall, Esq. | 1864 |
| " " (" II.) | ... | " | 1864 |
| " " (" III.) | ... | " | 1864 |
| " " (Balloch Castle) .. | 91 | A. L. D. Brown, Esq. | 1862- |
| " " (Luss) | ... | A. E. M ^c Dougall, Esq. | 1864 |
| " " (Stuckgown) | 100 | Capt. Ainsworth ... | C 1863- |
| Loch Long (Arddarroch) ... | 80 | J. White, Esq. | C 1848- |
| " " (Ardincaple) | ... | Lord Campbell | 1832-34 |
| " " (Arrochar) | 10 | A. E. M ^c Dougall, Esq. | 1862- |

DUMFRIESSHIRE.

| | | | | |
|-------|--|------|---------------------------------|---------------------|
| *B.A. | Annandale (Annan) | ... | Mr. Scott | C 1865- |
| | " (Applegarth Manse) .. | 180 | Rev. W. Dunbar ... | C 1827-51 T |
| | " (" School) .. | 224 | | C 1854-55 |
| | " (Dalton) | ... | | C 1854-55 |
| | " (Dryfesdale, Lockerbie) | 296 | | C 1854-55 |
| | " (Hutton Corrie Sch.) .. | 680 | | C 1854-55 |
| | " (Johnstone Goodhope) | 374 | | C 1854-55 |
| | " (Kirkmichael) | 239 | | C 1854-55 |
| | " (Kirkpatrick juxta) ... | 338 | Mr. R. Little | C 1854-59 |
| | " (Loch Maben) | 171 | | C 1854-55 |
| | " (Moffat, Evan Water School) | 549 | | C 1854-55 |
| | " (" Town) | 348 | | C 1854-55 |
| | " (Wamphray) | 317 | | C 1854-55 |
| | Dumfries | ... | Dr. Copland | 1776-93 imp. |
| | " (March Hill Cottage) | 70 | Mr. Hogg | 1850- |
| | " (Crichton Asylum) .. | 182 | Dr. Gilchrist | 1860- |
| | Eskdale (Canobie School) ... | 140 | J. Little, Esq. | C 1855, 1860, 1862- |
| | " (Carlesgill) | 370 | " | 1844, 1846, 1848, |
| | " (" Hill Top) .. | 1164 | " | 1850, 1860, 1862- |
| | " (Eskdalemuir) | 612 | " | 1856-60, 1862- |
| | " (Ettrick Pen Top) .. | 2265 | " | C 1855-60, 1862- |
| | " (Ewes) | 407 | " | 1856-60, 1862- |
| | " (Langholm) | 270 | " | C 1855-60, 1862- |
| | " (") | ... | Trans. Roy. Soc. Edin. | 1773-77 |
| | " (Westerkirk) | 420 | J. Little, Esq. | C 1855-60, 1862- |
| | Kippoch | ... | | 1832 |
| | Liddesdale (Whithaugh) | 400 | J. Little, Esq. | 1864 |
| | Nithesdale (Closeburn, Wallace Hall) ... | 206 | | C 1855-59 |
| | " (Drumlanrigg) | 186 | Mr. M ^c Intosh | 1856-62, 1864- |
| | " (Durrisddeer) | 459 | Edinb. Phil. Journ. | C 1855-58 |

DUMFRIESSHIRE (*continued*).

| Station. | Elevation. | Observer. | Period. |
|---|------------|------------------|-------------|
| Nithesdale (Glencairn, Hastings Hall) | 354 | | C 1855-59 |
| " (Keir) | 155 | | C 1855-59 |
| " (Kirkconnel) | 534 | | C 1855-59 |
| " (Morton, Thornhill) | 244 | | C 1855-59 |
| " (Penpont) | 195 | | C 1855-58 |
| " (Sanquhar) | 499 | | C 1855-58 |
| " (Tynron, Auchenbrack) | 629 | | C 1855-59 |
| " (Wanlockhead) | 1400 | Mr. Reid | C 1855-60 T |
| " (") | 1330 | Mr. Dawson | 1859- |

EDINBURGH.

| | | | |
|----------------------------------|---------------------------|----------------------|------------------------------|
| Barnton | ... | | 1804-9 |
| Calder (Cobbinshaw Loch)... | 863 | J. Deas, Esq. | C 1850- |
| " (Colzium) | ... | Ed. Phil. Journal... | 1856, 1859-61 |
| Colinton (Fernielaw) | 500 | J. Leslie, Esq. | C 1850- |
| Costorphine | ... | A. Paterson, Esq. | |
| Dalkeith (Park) | 183 | Mr. W. Thomson ... | 1851- |
| " | ... | | 1773-77, 1807-12,
1822-24 |
| Edinburgh | ... | Medical Essays..... | 1731-35 |
| " | ... | | 1792 imp. |
| " | ... | | 1808 |
| " | ... | | 1812 |
| " | ... | Capt. Kerr..... | 1852 |
| " (one mile from) ... | 250 | Dr. Playfair? | 1785-95 |
| " (Botanic Gardens) | 100 | Dr. Rutherford..... | 1796-99 |
| " (Canaan Cottage) | 246 | Mr. Adie | 1795-1805, 1822-47 |
| " (CharlotteSq., Green) | 230 | J. Leslie, Esq. | 1850- |
| " (" Roof) | 300 | " | 1847- |
| " (Hawkhill) | ... | Trans. Roy. Soc. Ed. | 1771-76 |
| " (March Hall) | 270 | A.K. Johnstone, Esq. | 1862-63 |
| " (Nelson Monument) | ... | | 1818-21, 1829 imp. |
| " (Observatory)..... | ... | | 1817-18 imp. |
| " (O. S. O., No. 1)... | 197 | Capt. O'Grady | 1854-58 T |
| " (" No. 2)... | 386 | " | C 1858-61 T |
| " (Prince's Gardens) | ... | Mr. Adie | 1860- |
| " (Regent's Terrace) | ... | " | |
| At Waterworks on Pentland Hills. | (Black Hills) | J. Leslie, Esq., and | 1847-49 imp. |
| | (" Spring) | A. Ramsay, Esq. | 1847 imp. |
| | (Cape Law Hill)..... | " " | 1850-54 imp. |
| | (Clubbiedean)..... | " " | 1847-49 imp., 1864- |
| | (Crawley Cottage) ... | " " | 1831-45 |
| | (Glencorse Cottage) | " " | 1846- |
| | (" Filters)..... | " " | 1852-59 |
| | (" Island)..... | " " | 1849-54 |
| | (Harlaw)..... | " " | C 1854- |
| | (Logan Lee) | " " | 1847-49 imp. |
| Inchkeith | 182 ? | Bd. of North. Lights | C 1813- |
| Musselburgh (Inveresk) | 60 | Mr. M'Auslane..... | 1837- |

ELGIN.

| | | | |
|----------------------------------|------|----------------------|------------------|
| Covesea Skerries | 59 ? | Bd. of North. Lights | C 1846- |
| Elgin | 28 | Dr. Geddes | 1856-61 |
| " (Ashgrove) | 33 | W. Topp, Esq. | 1862- |
| " (Anderson's Institution) | 38 | Mr. J. Martin | 1835-38, C 1862- |
| " (Urquhart) | ... | | 1795-97 imp. |
| Forres | 53 | Mr. M'Farlane | C 1860- |

FIFE.

| Station. | Elevation. | Observer. | Period. |
|-----------------------------|------------|-----------------------------------|---------|
| Burntisland | 80 | Mr. Macbean..... | C 1863- |
| Dunfermline (Waterworks) .. | ... | | 1853-59 |
| Isle of May | 182? | Bd. of North. Lights | C 1817- |
| Kirkcaldy (Abbotshall)..... | | | |
| Leven (Nookton) | 80 | W. M ^c G. Miller, Esq. | C 1857- |
| Markinch (Balfour) | 129 | Mr. Dewar | C 1857- |
| Pittenweem | 75 | Mr. Tennant..... | C 1831- |
| " (Balchrystie)..... | 135 | Mr. Forgan | 1841-51 |
| St. Andrews | ... | Statistical Account | 1835-36 |

FORFAR.

| | | | |
|-----------------------------|-----|-----------------------|----------------|
| Arbroath (Kepty Road) | 65 | A. Brown, Esq..... | 1844- |
| " | ... | Bd. of North. Lights | C 1840-52 T |
| Barry..... | 35 | Mr. Proctor | C 1856- |
| Dundee (Burnhead)..... | ... | | 1836-39 imp. |
| " (Constitution Road) | 60 | R. Adamson, Esq.... | 1853- |
| " (Craigton) | 440 | " | 1850- |
| " (Crescent) | ... | Mr. Fairweather .. | 1790-95 |
| " (Hill Head)..... | 500 | R. Adamson, Esq.... | 1836-41, 1844- |
| " (Kinloch) | ... | J. Leslie, Esq. | 1838 |
| " (Manse) | 450 | " | 1836-41 |
| " (Powder Magazine).... | ... | " | 1837-40 |
| " (Seichen) | 550 | R. Adamson, Esq.... | 1836-41, 1844- |
| " (Somerville Place)... | 240 | J. Kerr, Esq..... | C 1856- |
| " (Taybank) | 50 | | 1836-45 imp. |
| Glamis | ... | | 1836-38 |
| Kettins [Cupar Angus] | 218 | Mr. Gibb | 1856- |
| Montrose | 20 | J. Aberdein, Esq. ... | 1842-56 |
| " (Asylum) | 200 | Dr. Howden | 1864- |
| " (Bridge Street) ... | 25 | D. Scott, Esq. | C 1864- |
| " (High Street) | 21 | Mr. Leighton | C 1858- |
| " (Museum) | 8 | Mr. Campbell | 1857- |
| " (Usan) | 150 | Mr. Wyness | 1861- |

HADDINGTONSHIRE.

| | | | |
|-----------------------------|-----|--------------------|--------------|
| Drem (Dirleton) | ... | C. Stevenson, Esq. | 1847-52 imp. |
| " (Fenton Barns)..... | 100 | G. Hope, Esq. | 1863- |
| Dunbar (Thurston) | 320 | Mr. Mossman | C 1840- |
| Gifford (Yester) | 420 | Mr. Shearer | 1856- |
| Haddington (East Linton)... | 90 | Mr. Storie | C 1856- |
| " (Millfield) | 140 | Mr. Dods | 1835- |
| Prestonkirk (Smeaton)..... | 100 | Mr. Black | 1831- |

EAST INVERNESS-SHIRE.

| | | | |
|-------------------------------------|------|----------------------------------|---------|
| Beauley (Beaufort Castle) ... | 40 | Lord Lovat | 1860-63 |
| " (Belladrum)..... | ... | | |
| Fort Augustus (Inverie House) | ... | Mr. McDonald..... | C 1865- |
| " (Knorydant) ... | ... | J. Band, Esq. | C 1865- |
| Inverness (Culloden House) | 104 | A. Forbes, Esq. ... | 1855- |
| * " (Gordonville) | ... | W. Carruthers, Esq. | C 1865- |
| " (High School) | ... | J. Robertson, Esq... | C 1865- |
| " (Royal Academy) | 30 | M. Adam, Esq..... | 1829-31 |
| Kingussie | 800 | Mr. Rutherford ... | 1841-43 |
| *B.A. " (Laggan) | ... | Mr. A. M ^c Intosh ... | C 1865- |
| * " (Rothiemurchus)... | 700? | W. Grant, Esq. ... | C 1865- |
| *B.A. Loch Lochy (Clunes) | ... | Mr. A. C. M ^c Intyre | C 1865- |
| *B.A. Moy (Tamin)..... | ... | Mr. M ^c Dougall..... | C 1865- |
| *B.A. Strath Errick (Farraline) ... | 700 | Capt. Fraser | 1864- |
| *B.A. " (Migovie) | ... | Mr. M ^c Leod | C 1865- |
| Urquhart (Corrimony) | 320 | T. Ogilvy, Esq..... | C 1863- |

WEST INVERNESS-SHIRE.

| | Station. | Elevation. | Observer. | Period. |
|-------|-----------------------------|------------|----------------------|-------------------|
| *B.A. | Barrahead..... | 640? | Bd. of North. Lights | C 1833- [1863- |
| | Glen Quoich..... | 700 | Mr. Ballingal | 1853-56, 1858-59, |
| | Harris (Island Glass) | 50? | Bd. of North. Lights | C 1813- |
| | Skye (Kyleakin) | 3? | " | C 1857- |
| | " (Oronsay) | 15? | " | C 1857- |
| | " (Portree Moss Bank) .. | 30 | T. Fraser, Esq. | 1863 T |
| | " (" Poor House) .. | ... | Mr. McGrigor | C 1865- |
| | " (" Prison) | 60 | Mr. Grant | C 1860- |
| | " (" Waternish Manse) .. | ... | Rev. J. Lamont. | |
| | " (Raasay) | 80 | G. Rainey, Esq. ... | C 1851- |
| | " (Rona) | 196? | Bd. of North. Lights | C 1857- |
| | " (Sligachan) | ... | Mr. McKenzie | 1864- |
| | N. Uist (Baleloch) | 19 | Rev. J. A. Macrae... | 1860-65 T |
| | " (Loch Maddy) | 30 | C. Shaw, Esq. | C 1859- |
| | S. Uist (Ushenish) | 157? | Bd. of North. Lights | C 1857- |

KINCARDINESHIRE.

| | | | | |
|---|-----------------------------|-----|---------------------------------|----------------------------|
| † | Banchory House [Aberdeen] | 99 | A. Thomson, Esq. | 1835-49, 1855-57,
1859- |
| | " Ternan (Strachan) | 200 | Mr. McConnachie... | C 1854- |
| | Brechin (The Burn) | 237 | Col. M ^c Inroy | 1843- |
| | Fettercairn | ... | Mr. A. C. Cameron | C 1862- |
| | " (Balnakettle) | 450 | D. Scott, Esq. | C 1858-63 T |
| | " (Bogmuir) | 200 | R. Vallentine, Esq. | 1860- |
| | Girdleness [Aberdeen] | 86? | Bd. of North. Lights | C 1833- |
| | Lawrencekirk | ... | D. Robie, Esq. | 1856 |

KINROSS-SHIRE.

| | | | | |
|--|------------------|----|------------------|----------------|
| | Loch Leven | .. | Mr. Farnie | 1842-56, 1860- |
|--|------------------|----|------------------|----------------|

KIRKCUDBRIGHTSHIRE.

| | | | | |
|-------|------------------------------|-----|------------------------|-----------|
| *B.A. | Cargen [Dumfries] | 85 | P. Dudgeon, Esq. | C 1859- |
| | Carsphairn | ... | Mr. Hannah | C 1865- |
| | Castle Douglas (Slogarie) .. | 300 | T. R. Bruce, Esq. | 1864- |
| *B.A. | " (") .. | 800 | " | 1864- |
| | Dalbeattie | ... | Mr. Grieve | C 1865- |
| | Kells (Kenmuir Castle) | ... | " | (1832-38) |
| | Kirkcudbright (Little Ross) | 30? | Bd. of North. Lights | C 1843- |
| | New Galloway (Glenlee) .. | ... | W. Maxwell, Esq. | C 1865- |
| *B.A. | " (Waterside) .. | ... | P. Dalziel, Esq. | C 1865- |

LANARKSHIRE.

| | | | | |
|--|-----------------------------|-----|----------------------------|---|
| | Airdrie (Auchengray) | 650 | Dr. Rankin | C 1856-58 T |
| | " (Hillend House) | 620 | Mr. Thomson | C 1852- |
| | Avondale (Gilmourton) | 600 | Beardmore's Hydro-
logy | 1845-47 |
| | Douglas Castle | 783 | Mr. Russell | C 1860- |
| | " (Uddington) .. | 75 | Mr. Anderson | 1862- |
| | Glasgow | ... | " | 1765, 1775-78, 1788,
1795, 1805 imp. |
| | " | ... | " | 1851 |
| | " (Baillieston) | 230 | Mr. P. Jarvie | C 1856- |
| | " (Cessnock Park) .. | 34 | R. Hart, Esq. | 1850- |
| | " (Ibroxholm) | 20 | Messrs. Gardner ... | 1846-50, 1854-60 |
| | " (Macfarlane's Obs.) .. | 80 | " | C 1801-37 |
| | " (Observatory) | 200 | Prof. Grant | 1856-62, 1864 |
| | " (O. S. O.) | 166 | Major Bayly | C 1855-62 T |
| | " (Park) | ... | Messrs. Gardner ... | 1843-51 |

LANARKSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|--|-------------------------------|------------|----------------------|---------------|
| | Hamilton (Auchinraith) | 150 | R. Ker, Esq. | C 1853- |
| | " (") | ... | D. Alston, Esq. | 1833-46 |
| | " (Bothwell Castle) | 147 | Mr. Turnbull | 1807-21, 1844 |
| | Jerviston | ... | | 1830 imp. |
| | Lead Hills ¹ | 1280 | | 1813-20 imp. |

LINLITHGOW.

| | | | |
|------------------|-----|------------------|---------|
| New Liston | 165 | Mr. Gibson | 1857-59 |
|------------------|-----|------------------|---------|

THE ORKNEYS.

| | | | | |
|-------|---------------------------------|-----|-------------------------|------------------|
| | Hoy (Cantick Head) | ... | Bd. of North. Lights | C 1858- |
| | " (Graemsay, High, E.) | 27 | " | C 1851- |
| | " (" Low, W.) | ... | " | C 1851- |
| | " (Melsetter) | 55 | J. G. Heddle, Esq. | 1863- |
| *B.A. | Pomona (Holme Manse) | ... | Rev. O. Scott | C 1865- |
| | " (Inganess Cottage) | 190 | Dr. Baikie | C 1860-61 T |
| † | " (Kirkwall) | 8 | Mr. J. G. Iverach | C 1862- |
| † | " (Sandwick Lawn) | 78 | Rev. C. Clouston | 1840- |
| † | " (" North Park) | 94 | Bd. of " | 1862- |
| | N. Ronaldsay | 21 | Bd. of North. Lights | C 1854- |
| *B.A. | Papa Westray | ... | — Traill, Esq. | C 1865- |
| | Sanda (Start Point) | 29 | Bd. of North. Lights | C 1814-21, 1823- |
| | Shapinsa (Balfour Castle) | 50 | D. Balfour, Esq. | C 1856- |
| | Orkneys | ... | | 1811 imp. |

PEEBLES.

| | | | |
|-----------------------------|------|--------------------|------------------|
| Peebles | ... | | 1765-79 |
| " (Stobo Castle) | 600 | Mr. Anderson | 1857-59, 1861-62 |
| Pennyquick (North Esk Res.) | 1150 | Mr. Garnock | C 1850- |

PERTHSHIRE.

| | | | |
|------------------------------------|------|------------------------|------------------|
| Aberfeldy (Black Hill) | 823 | J. S. Hepburn, Esq. | C 1863- |
| " (Bolfracks) | 350 | Mr. Wylie | 1861- |
| " (Taymouth) | 370 | Mr. Murray | C 1861- |
| Annat Cottage [Dundee] | 170 | Mr. Gorrie | C 1846-57 T |
| Auchterarder House | 172 | Lieut.-Col. Hunter | C 1860- |
| " (Colquhalzie) | 100 | J. S. Hepburn, Esq. | 1857- |
| " (Trinity Gask) | 133 | Mr. Wylie | C 1856- |
| Blairgowrie (Rosemount) | 300 | Mr. Gibb | 1863- |
| " (Clunie Manse) | ... | Rev. W. Macritchie | 1834-36- |
| Callander (Blairhoyle) | ... | Mr. Munro | C 1862- |
| " (Lanrick Castle) | 150 | A. Glover, Esq. | 1853-62, 1864- |
| " (Leny) | 345 | J. B. Hamilton, Esq. | 1852-55, 1860- |
| Crieff (Muthill) | 247 | Rev. A. J. T. Morris | C 1863- |
| " | ... | Mr. M'Owen. | |
| Doune (Deanston) | 130 | J. Finlay, Esq. | C 1837- |
| " (Gartincaber) | ... | J. B. Murdoch, Esq. | 1853-60 |
| Dunblane (Kippenross) | 100 | J. Stirling, Esq. ... | 1852- |
| Errol. | | | |
| Loch Earn Head (Balquhiddie) | ... | | 1846-47 T |
| " (Stronvar) | 463 | D. Carnegie, Esq. | 1853-54, 1859- |
| Loch Katrine (Aberfoyle) | 60 | J. M. Gale, Esq. ... | C 1853- |
| " (Bridge of Earn) | ... | " | 1855 imp. |
| " (" Turk) | 270 | " | C 1853- |
| " (Glen Finlas) | 1800 | " | C 1853-55, 1857- |

¹ See also Dumfriesshire, Wanlockhead.

PERTSHIRE (*continued*),

| | Station. | Elevation. | Observer. | Period. |
|--------|------------------------------|------------|----------------------|------------------|
| | Loch Katrine (Glen Gyle) ... | 380 | J. M. Gale, Esq. ... | C 1853- |
| | " (Ledard) | 1500 | " | C 1853- |
| | " (Loch Dhu)..... | 325 | " | C 1861- |
| | " (" Drunkie) | 420 | " | C 1861- |
| | " (" Lubnaig) | ... | " | 1846-48 imp. |
| | " (" Vennachar) | 275 | J. M. Gale, Esq. ... | C 1861- |
| | " (Tunnel Hill Top) | 830 | " | C 1861- |
| * B.A. | Logierait | ... | Rev. G. D. R. Munro | C 1865- |
| | " (Mouline) | ... | " | (1813-18) |
| | Meikle (Belmont) | 300 | Mr. Stewart | 1860-61 |
| | " (" Castle) ... | 204 | Mr. Robertson | 1789-95, 1799 |
| | Perth Academy..... | 79 | Dr. Miller..... | 1852-54, 1856- |
| | " (Early Bank)..... | 66 | Gen. Lindsay | C 1845-62 |
| | " (Kinfauns) | 185 | Rev. R. Gordon ... | C 1817-25 |
| | " (" Castle) | 20 | Earl Gray | 1815-30, 1832-43 |
| | " (" Tower)..... | 129 | " | 1815-30, 1832-41 |
| | " (Methven) | ... | " | 1830-36 imp. |
| | " (Rose Bank) | 130 | Rev. R. Gordon ... | C 1812-16 T |
| | " (Scone Palace) | 80 | Mr. Halliday | 1860- |
| | St. Fillans (Dunira). | | | |
| | Stanley | 200 | Rev. W. Mather ... | C 1833- |
| | Tyndrum (56°24'N., 4°42'W.) | 792 | Mr. M'Laren | 1857-61 imp. |

RENFREWSHIRE.

| | | | | |
|---|----------------------------------|-----|-----------------------|------------------|
| | Eaglesham (Cross Keys)..... | 600 | J. Arneil, Esq. | 1864- |
| | " (Revoch) | 700 | Mr. Scott | 1862, 1864- |
| | Gorbals (Black Loch) | 700 | J. M. Gale, Esq. ... | 1854-58, 1861- |
| | " (Middleton) | 550 | " | 1854- |
| | " (Ryat Linn) | 310 | " | 1854-58, 1860- |
| | " (Waulk Glen) | 280 | " | 1854-58, 1860- |
| | " | 296 | " | 1849-50, 1852 |
| | Greenock | ... | " | 1833 |
| | " | 30 | Capt. M'Kellan..... | 1846-49 |
| | " (Bagatelle) | ... | " | 1847-55 |
| | " (Hamilton Street) | 50 | J. Gardner, Esq. ... | 1853- |
| | " (Infirmary) | 120 | " | 1820-38 |
| | " (" Garden) | ... | " | 1836-37 imp. |
| | " (Shaws W. works I.) | 600 | P. Morison, Esq. ... | 1864- |
| | " (" II.) | 560 | " | 1864- |
| | " (" III.) | 800 | " | 1864- |
| | " (" IV.) | 540 | " | 1864- |
| | " (" Everton Cottage) | 472 | " | 1864- |
| | " (" Mean of 5 gauges) | ... | " | 1835-39, 1841-55 |
| | Johnstone (Castle Sempole) ... | 180 | D. Robie, Esq. | 1827-33 |
| | " (Kilbarchan) | 350 | " | 1860- |
| | Lanfane | ... | " | 1831 |
| | " (House) | ... | " | 1831-52 |
| | " (Old Gauge) | ... | " | 1831 |
| | Langside | ... | " | 1831-33, 1835-37 |
| * | Lochwinnoch (Lochside Ho.) | ... | J. C. Burns, Esq. ... | C 1865- |
| | Mearns (Nither Place) | 350 | W. Mather, Esq. ... | 1841-50, 1860- |
| | Paisley | | | |
| | " (Back Thornly Muir) | 693 | Statistical Account | 1836 imp. |
| | " (Craig Park) | 379 | " | 1849-50 imp. |
| | " (Ferguslie House) ... | 85 | Mr. Stewart | 1858- |
| | " (Locherfield)..... | ... | Mr. Hardie | 1861-62 |
| | " (Nether Craigs) | 160 | Statistical Account | C 1834-36 |
| | " (Orr Square) | 62 | " | 1836 imp. |

ROSS-SHIRE, EAST.

| | Station. | Elevation. | Observer. | Period. |
|--------|-------------------------------|------------|----------------------|------------------|
| | Alness (Ardross Castle) | 450 | Mrs. Matheson | 1862- |
| | Cromarty | 28 | Bd. of North. Lights | C 1846- |
| | Dingwall | ... | Statistical Account | 1830-35 |
| | " (Brahan Castle) .. | ... | K. S. M'Kenzie, Esq. | C 1865- |
| * B.A. | " (Free Church Inst.) .. | ... | J. Boyd, Esq. | C 1865- |
| * | Invergordon Castle | ... | A. E. Maclure, Esq. | C 1865- |
| | Tain | 90 | — Gordon, Esq. ... | 1862-63 |
| * B.A. | " (Fearn) | 48 | Mr. Maclean | C 1865- |
| | Tarbetness | 61 | Bd. of North. Lights | C 1830-56, 1861- |

ROSS-SHIRE, WEST.

| | | | | |
|--------|--------------------------|-----|------------------------|--------------|
| * B.A. | Applecross | 50 | Dr. Haynes | C 1865- |
| | Lewis (Bernera) | 15 | Mr. Matheson | C 1859- |
| | " (Butt of) | ... | Bd. of North. Lights | C 1863- |
| | " (Galson) | 65 | Rev. J. Gunn | 1856-58 imp. |
| | " (Stornoway) | 31 | Bd. of North. Lights | C 1859- |
| | " (Lewis Castle) | 70 | Sir J. Matheson, Bart. | 1853- |
| | " (Uig Lodge) | ... | Mr. J. M'Kay. | |
| B.A. | Loch Broom | 30? | Mr. M'Leary | C 1865- |
| * | " Duich (Inverinate Ho.) | 100 | Mrs. Matheson | C 1864- |
| | " " (Shiel House) .. | 30 | A. E. M'Dougall, Esq. | 1860 |

ROXBURGHSHIRE.

| | | | | |
|---|----------------------------|------|------------------------|--------------------|
| | Hawick (Borthwick Brae) .. | 800 | A. E. Lockhart, Esq. | C 1860- |
| | " (Branxholm) | ... | Trans. Roy. Soc. Edin. | 1773-83 |
| | " (Falnash) | 800? | Mr. Turnbull | 1862- |
| | " (Goldielands) | 505 | Dr. Elliot | 1862- |
| | " (Kirkton) | ... | Mr. Welsh | 1862- |
| | " (Langraw) | 570 | Mr. Oliver | 1862- |
| | " (Linton) | ... | Mr. Barton | 1863- |
| * | " (Lynnwood) | 387 | Mr. Nixon | 1862- |
| * | " (Menslaws) | ... | Mr. Cockburn | 1862- |
| | " (Sillerbit Hall) | ... | Mr. Elder | C 1865- |
| | Jedburgh (Sunnyside) | 333 | G. Hilson, Jun., Esq. | C 1864- |
| | Kelso | 120 | Tweedside Nat. Club | 1840-43 |
| | " (Springwood Park) .. | 130 | Sir G. Douglas, Bart. | 1864- |
| | Makerstoun | 213 | Mr. Hogg | 1855-59 |
| | " (Garden, 6½ ft.) .. | 171 | Trans. Roy. Soc. Edin. | 1832-45 |
| | " (Greenhouse, 18 ft.) | 192 | " " | 1837-45 |
| | " (Observatory) | ... | " " | C 1842-45, 1847-53 |
| | " (Blagden Cur) .. | 1783 | Tweedside Nat. Club | 1842-44 |
| | " (Grange of Hownam) | 367 | Trans. Roy. Soc. Edin. | 1840-43 imp. |
| | Roxburgh (Sunlawshill) .. | ... | | 1862-63 |
| | Yetholm (Mowhaugh) | 612 | Mr. Carter | 1863- |

SELKIRKSHIRE.

| | | | | |
|--|-----------------------|-----|------------------------|---------|
| | Bowhill | 597 | Mr. Mathieson | 1856- |
| | Roberton (Wool) | ... | Trans. Roy. Soc. Edin. | 1773-76 |

THE SHETLANDS.

| | | | | |
|--|----------------------------|-----|----------------------|------------------|
| | Bressay (Lighthouse) | 72 | Bd. of North. Lights | C 1859- |
| | " (Manse) | 12 | Rev. Z. M. Hamilton | C 1849- |
| | East Yell | 176 | Mr. Mathewson | C 1858- |
| | Sumburghead | 265 | Bd. of North. Lights | C 1822-24, 1826- |

STIRLINGSHIRE.

| | | | | |
|--|------------------|------|----------------------|---------|
| | Ben Lomond | 1800 | J. M. Gale, Esq. ... | C 1853- |
| | Drymen | ... | Rev. A. Lochore ... | 1834-37 |

STIRLINGSHIRE (*continued*).

| | Station. | Elevation. | Observer. | Period. |
|--|--|------------|----------------------|------------------|
| | Fintry Hills (Source of the Endrick) | 750 | | 1853-55 T |
| | Millfield (Gardens) | 165 | J. Miller, Esq. | 1863- |
| | „ (House)..... | 169 | Mr. Scott | 1849-54, 1856-59 |
| | Monteith (Cardross)..... | ... | Mr. Wyber | 1860- |
| | Polmont | ... | | (1821-37) |
| | Stirling (Ordnance S. O.)..... | 233 | | 1858-60 |
| | „ (Polnaise Gardens)... | 12 | Mr. Gorrie..... | 1852- |
| | Strathblane (Carbeth) | 470 | W. Smith, Esq..... | C 1815- |
| | „ (Mugdock Res.).. | 320 | J. M. Gale, Esq. ... | C 1862- |

SUTHERLANDSHIRE.

| | | | | |
|-------|-------------------------------|-----|-----------------------|----------------------|
| | Cape Wrath | 355 | Bd. of North. Lights | C 1829- |
| | Golspie (Dunrobin Castle) ... | 6 | Mr. Mitchell | C 1860- |
| *B.A. | Helmsdale..... | 34 | Mr. Campbell | C 1865- |
| | Lairg (Invershin) | 20 | Mr. Young..... | 1863- |
| | Scourie | 20 | J. Simpson, Esq. ... | C 1856-61, 1862 imp. |
| | Tongue House | 33 | J. Crawford, Esq. ... | C 1856- |

WIGTONSHIRE.

| | | | | |
|-------|-------------------------------|-----|----------------------|---------|
| | Corsewall | 22 | Bd. of North. Lights | C 1816- |
| | Mull of Galloway..... | ... | „ | C 1832- |
| | Stranraer (Castle Kennedy)... | ... | Mr. Burnett | 1837 |
| | „ (South Cairn) | 209 | Mr. Kennedy..... | C 1859- |
| *B.A. | Wigton (North Balfarn) | ... | W. MacLelland, Esq. | C 1865- |

IRELAND.

ANTRIM.

| | | | | |
|-------|--------------------------------|-----|----------------------|---------------------------|
| *B.A. | Antrim | 150 | Rev. J. H. Orr | C 1864- |
| | Belfast (Harbour Office) | 47 | O. Shaw, Esq. | 1863- |
| † | „ (Linen Hall)..... | 12 | Mr. Stevens | C 1796-99 T |
| † | „ (Queen's College)..... | 58 | Mr. Bell..... | C 1812-32 imp. 1835-1851- |

ARMAGH.

| | | | | |
|--|--------------------------|-----|---------------------|-------|
| | Armagh Observatory | 247 | Rev. Dr. Robinson . | 1836- |
|--|--------------------------|-----|---------------------|-------|

CAVAN.

| | | | | |
|-------|---------------------------|-----|------------------------|---------|
| *B.A. | Bawnboy (Owendoon)..... | 218 | G. H. L'Estrange, Esq. | C 1864- |
| * | Belturbet (Redhills)..... | ... | Rev. E. B. W. Venables | C 1864- |
| | Cavan | 230 | J. Price, Esq..... | C 1863- |

CLARE.

| | | | | |
|-------|--------------------------|-----|---------------------|---------|
| *B.A. | Ennis..... | 35 | Rev. S. L. Breakey | C 1864- |
| | Killaloe | 128 | Rev. C. Mayne | C 1846- |
| | „ (5 in. + ground) | 123 | „ | 1861-63 |

CORK.

| | | | | |
|-------|----------------------------|-----|-----------------------|----------------------|
| | Cork (Queenstown) | ... | Dr. Scott | 1844-48 imp, |
| | „ (Queen's Collège) | 65 | Prof. England | 1862- |
| | „ (Royal Institution)..... | 80 | R. Caulfield, Esq.... | 1838, 1851-52, 1860- |
| *B.A. | Dunmanway | ... | Mr. Donovan..... | C 1865- |
| | Fermoy | ... | Mr. Campbell. | |

DONEGAL.

| | Station. | Elevation. | Observer. | Period. |
|-------|-------------------|------------|----------------------|---------|
| *B.A. | Letterkenny | 107 | Rev. H. Kingsmill... | C 1864- |
| | Milford | 230 | Rev. A. Delap | C 1864- |

DOWN.

| | | | | |
|--|-----------------------------|-----|-----------------------|-----------|
| | Ardglass Castle..... | ... | A. Beauchlerk, Esq. | |
| | Banbridge (Milltown) | 200 | J. Smith, jun., Esq. | C 1861- |
| | " (" 40 ft.) | 240 | " | 1864- |
| | " (Bann Reservoir) | 440 | " | C 1861- |
| | Downpatrick (Seaford) | 208 | " | 1863- |
| | Holywood (Green Mount) ... | ... | G. W. Kyle, Esq. | (C 1865-) |
| | Lurgan (Waringstown) | 190 | T. Waring, Esq. ... | C 1861- |

DUBLIN.

| | | | | |
|--|-------------------------------|-----|-----------------------|------------------|
| | Dublin | ... | A. Semple, Esq. | 1823-24 |
| | " (Black Rock) | 95 | T. Bewley, Esq. | 1840- |
| | " (Broadstone Station) | 95 | J. Price, Esq. | C 1863- |
| | " (Cavendish Row) | ... | Dr. Kirwan | 1791-1808 |
| | " (Clonsilla) | 220 | J. Price, Esq. | C 1863- |
| | " (College of Surgeons) | ... | " | 1839-44 |
| | " (Glasnevin) | 66 | D. Moore, Esq. | 1860- |
| | " (Monkstown) | 100 | A. Pim, Esq. | C 1859- |
| | " (" 40 ft.) | 140 | " | C 1864- |
| | " (" 90 ft.) | 200 | " | C 1861- |
| | " (Phoenix Park) | 166 | Capt. Wilkinson, R.E. | C 1837-52 T |
| | " (") | ... | " | C 1853-55, 1861- |
| | " (Trinity College) | 42 | Rev. Prof. Galbraith | C 1841-60, 1863- |
| | " (Vicar's Lodge) | 89 | S. Yeates, Esq. | 1843-60, 1862- |
| | " | ... | " | 1835-39 imp. |

FERMANAGH.

| | | | | |
|--|------------------------------|-----|---------------------|----------------------|
| | Enniskillen (Florence Court) | 300 | Earl of Enniskillen | 1844-45, 1854, 1856- |
| | " (Royal School, Portora) | ... | Mr. Steel. | |

GALWAY.

| | | | | |
|-------|-----------------------------|-----|-------------------------|-----------|
| | Galway | 40 | J. Price, Esq. | C 1863- |
| | " (Drainage Office) .. | 40 | G. H. D'Arcy, Esq. | 1852-60 |
| | " (Prospect) | ... | " | 1838 imp. |
| | " (Queen's College) ... | 25 | Prof. Curtis | C 1861- |
| *B.A. | Gort (Creg Park) | 130 | R. J. Lattey, Esq. | C 1864- |
| | Outerard (Innishambo) | ... | J. D'Arcy, Esq. | C 1864- |

KERRY.

| | | | | |
|-------|-------------------------------|-----|---------------------|---------|
| *B.A. | Killarney | ... | Mr. Spillane | C 1865- |
| *B.A. | " | ... | " | C 1865- |
| | Knights Town (Valentia) | 30 | The Knight of Kerry | 1861- |

KILKENNY.

| | | | | |
|-------|----------------------------|-----|-----------------------|---------|
| | Inistogue (Woodford) | ... | Rt. Hon. W. F. Tighe | C 1865- |
| | Kilkenny | 200 | Messrs. Duffy & Boyd | 1863- |
| | " (Gowran Castle) ... | ... | Rt. Hon. Lord Clifden | C 1865- |
| *B.A. | Stoneyford (Inisnag) | ... | Rev. J. Graves | C 1865- |

KING'S COUNTY.

| | | | | |
|--|-------------------------------|-----|---------------------|---------|
| | Cangort Park [Roscrea] | 340 | H. B. Trench, Esq. | C 1863- |
| | Parsonstown (Birr Castle) ... | 200 | Earl of Rosse | 1862- |
| | Tullamore | 235 | H. J. B. Kane, Esq. | 1850- |

LIMERICK.

| | | | | |
|---------|----------------------|-----|-----------------------|---------|
| | Limerick | ... | Rev. C. Mayne | 1861 |
| * 1865. | " (Blackwater) | 92 | S. Caswell, Esq. | C 1864- |

LONDONDERRY.

| | Station. | Elevation. | Observer. | Period. |
|---|--------------------------------|------------|----------------------|----------------|
| * | Garvagh (Moneydig) | 120 | H. R. Morrison, Esq. | C 1864- |
| | Londonderry | ... | | 1797-1800 imp. |
| | „ (Literary Association) | 50 | Dr. Cuthbert..... | 1861- |
| | „ | 150 | D. Watt, Esq. | C 1862- |

LONGFORD.

| | | | | |
|--|----------------------------|-----|----------------------|---------------|
| | Drumcashel | ... | | (1865) |
| | Edgeworthstown | ... | H. Edgeworth, Esq. | 1798, 1807-08 |
| | „ | ... | Mrs. Butler | 1862-63 T |
| | Longford (Viewmount) | ... | M. W. O'Connor, Esq. | C 1864- |

MAYO.

| | | | | |
|--|-------------------------|-----|---------------------|---------------|
| | Castlebar | 130 | J. Price, Esq. | C 1863- |
| | Cong | ... | G. H. D'Arcy, Esq. | 1852-56, 1860 |
| | „ (Ashford Court) | ... | — Guinness, Esq. | |

MEATH.

| | | | | |
|--|----------------|-----|------------------------|-----------|
| | Moynalty | ... | J. D. Fanell, Esq. ... | (C 1861-) |
|--|----------------|-----|------------------------|-----------|

QUEEN'S COUNTY.

| | | | | |
|--|--------------------|-----|---------------------|---------|
| | Portarlinton | 236 | M. Hanlon, Esq. ... | C 1844- |
|--|--------------------|-----|---------------------|---------|

ROSCOMMON.

| | | | | |
|-------|----------------|-----|--------------------|---------|
| *B.A. | Holywell | ... | H. Smyth, Esq..... | C 1864- |
|-------|----------------|-----|--------------------|---------|

SLIGO.

| | | | | |
|-------|------------------------------|-----|----------------------|---------|
| *B.A. | Bunninadden (Doo Castle) ... | ... | Mr. O'Dowd..... | C 1864- |
| | Collooney (Markree) | 145 | Mr. Smith..... | C 1833- |
| | Sligo (Hazlewood) | 45 | Rt. Hon. J. Wynne... | C 1863- |
| | „ (Railway Station) | 50 | J. Price, Esq. | C 1863- |

TIPPERARY.

| | | | | |
|-------|--------------------------------|------|----------------------|----------|
| *B.A. | Borrisoleigh (Ballinlonty) ... | ... | Mr. Kearns | C 1865- |
| | Cashel (Ballywalter) | 300? | L. Cust, Esq..... | C 1864 T |
| * | Tipperary (Ballytristreen) ... | ... | J. Bolton, Esq. | C 1865- |
| | „ (Cordaggan House) | 300? | L. Cust, Esq..... | C 1864- |

TYRONE.

| | | | | |
|--|------------------------------|-----|--------------------|---------|
| | Strabane (Leckpatrick) | 260 | Rev. J. C. Maxwell | C 1861- |
|--|------------------------------|-----|--------------------|---------|

WATERFORD.

| | | | | |
|--|----------------------------|-----|-----------------|----------------------|
| | Waterford (Newtown School) | 60 | Mr. Greer | 1840-49, 1852, 1860- |
| | „ (Portlaw) | ... | Mr. Free | C 1841- |
| | „ (Rathculliheen) ... | 140 | | 1859- |

WESTMEATH.

| | | | | |
|--|---------------|-----|---------------------|---------|
| | Athlone | 150 | J. Price, Esq. | C 1863- |
|--|---------------|-----|---------------------|---------|

WEXFORD.

| | | | | |
|-------|---------------------------|-----|-----------------------|---------|
| *B.A. | Gorey (Courtown) | ... | Earl of Courtown... | C 1864- |
| | Wexford | 85 | J. D. Farrell, Esq... | 1863- |
| | „ (Reclaimed Lands) | 1 | C. M. Palliser, Esq. | 1863- |

WICKLOW.

| | | | | |
|--|-----------------------|-----|---------------------|---------|
| | Bray (Fassaroe) | 250 | E. Barrington, Esq. | C 1853- |
|--|-----------------------|-----|---------------------|---------|

On the Strength of Materials considered in relation to the Construction of Iron Ships. By WILLIAM FAIRBAIRN, LL.D., F.R.S., &c., and THOMAS TATE, Esq.*.

1. IN the following investigation it will be assumed that, under the action of equal forces, the extension of the fibres of a beam will be equal in amount to their compression, and that the amount of the extension or compression, as the case may be, is proportional to the magnitude of the force producing it; and in order to render this hypothesis more fully in accordance with the fact that the ultimate resistances of the two forces of compression and extension in a beam are in almost all cases different, it will be further assumed that the material reaches its ultimate limit of resistance to the one force before it reaches its ultimate limit of resistance to the other force.

SECTION I.

On the Qualities of Iron best adapted for Iron Ships, especially Ships of War.

2. The work expended in the elongation or compression of a bar is equal to one-half the force multiplied by the corresponding elongation. Moreover, for bars of the same material, the work varies as the solid content of the bar; that is,

$$U = uKL, \dots\dots\dots (1)$$

where U = the work of elongation, K = the section of the bar in square inches, L = its length in feet, and u a constant for each class of material, being the work done upon a bar 1 foot long and 1 square inch in section. Hence

$$u = \frac{U}{KL} = \frac{1}{2} \frac{Pl}{KL}, \dots\dots\dots (2)$$

which determines the value of u from experimental data for different kinds of material, where P is the strain in lbs., and l is the extension of the bar corresponding to this strain.

3. The value of u , determined for different kinds of material, gives us a comparative measure of their powers of resistance to a strain of the nature of impact, or of dynamic effect; hence the coefficient u may be called the *modulus of dynamic resistance*, or, as Tredgold named it, the *modulus of resilience*. It is presumed that the best kind of iron for resisting the impact of shot or shell is that whose modulus of dynamic effect is greatest.

4. The values of u , determined by Mr. Fairbairn's experiments for different plates or bars of iron, show that the dynamic resistance of thick plates to rupture is about twice and a half that of thin ones, that the resistance of thick steel plates is about one-tenth greater than that of the Low Moor iron plates A, and that the resistance of these latter plates is one-half greater than that of the rolled plates D.

5. Similarly the work expended in the deflection of a bar supported at its extremities, by a force applied at its centre, is equal to one-half the pressure multiplied by the corresponding deflection; and, moreover, we also have

$$U = uKL, \dots\dots\dots (3)$$

where u , the *modulus of dynamic resistance*, being constant for the same kind of material, gives us a comparative measure of the resistance of different kinds of material to a force of impact tending to produce transverse rupture.

* In this inquiry Mr. Tate has deduced useful formulæ from Mr. Fairbairn's experiments—independent of other researches—on the strength of iron ships.

SECTION II.

Transverse Strains produced on a Ship under various conditions.

6. The value of M , or the strain tending to rupture a beam, depends on the magnitude and the relative position of the pressures applied to the beam.

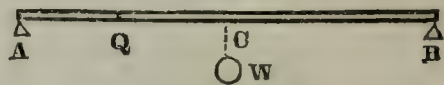
When the pressure W is applied at the middle of the beam AB , supported at its extremities (fig. 1), the pressure

Fig. 1.

on the support at A is equal to $\frac{W}{2}$; and

the moment M_1 of this pressure tending to rupture the beam at *any* point,

Q , is equal to the product of the pressure $\frac{W}{2}$ by its leverage AQ ; that is,



$$M_1 = \frac{W}{2} \times AQ \dots \dots \dots (4)$$

Now this will become a maximum when $AQ = AC$; that is, the greatest strain will take place at the centre of the beam, or at the point where the weight is applied.

7. A beam AB , fixed at the extremity B , is acted upon by a series of vertical pressures, $p_1, p_2, \dots \dots p_n$, whose distances from B are respectively $a_1, a_2, \dots \dots a_n$. To find the value of M .

Here the greatest strain must take place at B ;

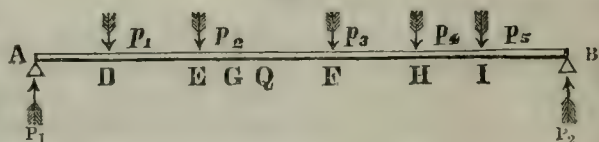
$$\therefore M = p_1 a_1 + \dots \dots + p_n a_n = (p_1 + \dots \dots p_n) GB, \dots \dots \dots (5)$$

where GB is the distance of the centre of gravity of all the pressures from the point of support B .

8. A beam AB , supported at its extremities, is acted upon by a series of pressures on each side of the central pressures p_2, p_3, p_4 , applied at the points E, F, H . To find the greatest value of M .

Fig. 2.

Let p_1 be the resultant of the pressures applied between A and E , and p_5 the resultant of those applied between B and H .



By the principle of the equality of moments, we get

$$\begin{aligned} P_1 &= \frac{1}{AB} (p_1 \times DB + p_2 \times EB + p_3 \times FB + p_4 \times HB + p_5 \times IB) \\ &= \frac{1}{AB} (p_1 + \dots \dots + p_5) GB = \frac{W \times GB}{AB}, \dots \dots \dots (6) \end{aligned}$$

which gives the pressure on the prop A , where W is put for the sum of the pressures, and G is their centre of gravity.

Supposing Q , lying between the pressures p_2 and p_3 , to be the point corresponding to the greatest strain, or, in fact, the point where rupture would take place in a beam of uniform dimensions.

Now when the lever AQ turns on Q as a centre, we get

$$\begin{aligned} M &= P_1 \times AQ - (p_1 \times DQ + p_2 \times EQ) \\ &= (P_1 - p_1 - p_2) AQ + p_1 \times AD + p_2 \times AE \\ &= \frac{AQ}{AB} \left\{ W \times GB - AB (p_1 + p_2) \right\} + p_1 AD + p_2 AE \dots \dots \dots (7) \end{aligned}$$

by substituting the value of P_1 given in equation (6).

Substituting the value of $W \times GB$ given in equation (6), and putting g_1 for the distance of the centre of gravity of p_1, p_2 from A, and g_2 for that of p_3, p_4, p_5 from B, we get

$$M = \frac{AQ}{AB} \left\{ (p_3 + p_4 + p_5) g_2 - (p_1 + p_2) g_1 \right\} + (p_1 + p_2) g_1 \dots \dots \dots (8)$$

By *interchanging* the symbols of this expression, the moment taken in reference to the pressure P_2 will be

$$M = \frac{BQ}{AB} \left\{ (p_1 + p_2) g_1 - (p_3 + p_4 + p_5) g_2 \right\} + (p_3 + p_4 + p_5) g_2 \dots \dots \dots (9)$$

This expression may be shown to be identical with the former by putting $AB - AQ$ for BQ .

Similarly, supposing the point Q to lie between F and H, we get

$$M = \frac{AQ}{AB} \left\{ W \times GB - AB (p_1 + p_2 + p_3) \right\} + p_1 \times AD + p_2 \times AE + p_3 \times AF. (10)$$

Now, if the quantity within the brackets of equation (7) is positive, while that of equation (10) is negative, the value of M expressed by equation (7) will increase with AQ , attaining a maximum at F; on the other hand, the value of M expressed by equation (10) will increase as AQ is decreased, attaining a maximum at F; hence it follows that the point F under these conditions will undergo the greatest strain, and equation (7) will express the maximum value of M by substituting AF for AQ , the test for the point F of greatest strain being as follows:—

$$W \times GB - AB (p_1 + p_2) = \text{positive} \dots \dots \dots (P)$$

$$W \times GB - AB (p_1 + p_2 + p_3) = \text{negative} \dots \dots \dots (N)$$

Example.—Let $AB=40, p_1=6, p_2=10, p_3=20, p_4=8, p_5=6$ tons, $DB=32, EB=25, FB=22, HB=12, IB=4$. Then from (P) and (N) we find that F is the point of greatest strain, and from equation (7) we find M , the greatest moment tending to rupture the beam, to be 361 nearly.

9. When $W \times GB = AB (p_1 + p_2)$, or $(p_3 + p_4 + p_5) g_2 = (p_1 + p_2) g_1$, eq. (7) becomes

$$M = p_1 \times AD + p_2 \times AE. \dots \dots \dots (11)$$

Now as this expression is independent of AQ , it follows that *the value of M is the same* for all points lying between E and F. This remarkable result may be readily verified by observing that in this case $P_1 = p_1 + p_2$.

When there are only two pressures, p_2, p_3 , applied to the beam—that is, when $p_1 = p_4 = p_5 = 0$ (see fig. 3), then equation (8) becomes

$$M = \frac{AQ}{AB} (p_3 \times BF - p_2 \times AE) + p_2 \times AE. \dots \dots \dots (12)$$

If $p_3 \times BF > p_2 \times AE$, then M becomes a maximum at F; that is, $AQ = AF$. When $p_3 \times BF = p_2 \times AE$, then this expression becomes

$$M = p_2 \times AE, \text{ or } p_3 \times BF, \dots \dots \dots (13)$$

which, being independent of AQ , shows that the moment is constant for all points lying between E and F.

10. When a ship has its load unequally distributed throughout its length, to find the point of maximum strain, &c., the ship being supported at the extremities A and B.

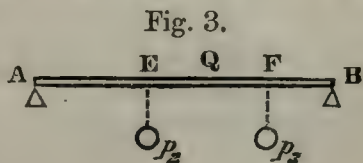
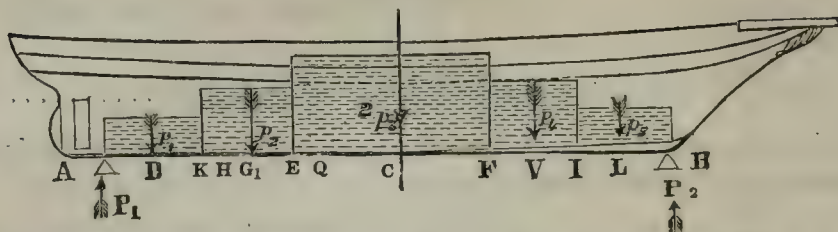


Fig. 4.



Suppose the ship to be uniformly loaded over the parts AK, KE, &c., and let p_1, p_2 , &c. be the loads over these parts respectively. Put $l=AB$; $k_1=AE$; $k=EF$; $k_2=FB$; $a=CB$, the centre of gravity of EF being at C; w_1 =the weight of the mass over AE, g_1 =the distance of its centre of gravity from A; w_2 =the weight of the mass over FB, g_2 =the distance of its centre of gravity from A; $2p_3$ =the weight of the mass over EF; $x=AQ$, the greatest strain being supposed at Q; then

$$P_1 = \frac{1}{l} \left\{ w_1(l-g_1) + 2p_3 a + w_2 g_2 \right\} \dots \dots \dots (1)$$

$$M = P_1 \times AQ - w_1(AQ-g_1) - \frac{2p_3}{k} \times (AQ-AE) \times \frac{1}{2} AQ-AE$$

$$= P_1 x - w_1(x-g_1) - \frac{p_3}{k}(x-k_1)^2; \dots \dots \dots (2)$$

$$\therefore \frac{dM}{dx} = P_1 - w_1 - \frac{2p_3}{k}(x-k_1) = 0, \text{ when } M \text{ is a max.};$$

$$\therefore x = \frac{1}{2p_3} \left\{ k(P_1 - w_1) + 2k_1 p_3 \right\} \dots \dots \dots (3)$$

Substituting the value of P_1 given in equation (1), this expression determines the point Q of greatest strain; and substituting the values of P_1 and x , here found, in equation (2), the maximum value of M will be determined.

(1) If $w_1 g_1 = w_2 g_2$, and $k_1 = k = k_2 = \frac{l}{3}$, then from equation (1) we get

$$P_1 = w_1 + p_3,$$

which, substituted in equation (3), gives $x = \frac{l}{2}$; that is, the point of greatest strain is at the centre.

Again, substituting these values in equation (2), we get

$$M = \frac{5}{12} p_3 l + w_1 g_1 \dots \dots \dots (4)$$

(2) If $2p_3 = 0$, and $w_1 g_1 = w_2 g_2$, then $P_1 = w_1$, and $M = w_1 g_1$, which expresses the moment tending to rupture all points lying between E and F.

11. Suppose the length of the ship to be divided into six equal spaces, AK, KE, EC, CF, FI, IB, the loads on each part being $p_1, p_2, p_3, p_3, p_4, p_6$ respectively; then

$$\dots \dots \dots AK = KE = \&c. = \frac{l}{6}, \text{ and}$$

$$P_1 = \frac{1}{l} \left\{ p_6 \times LB + p_4 \times VB + \&c. \right\} \\ = \frac{1}{12} \left\{ p_6 + 3p_4 + 5p_3 + 7p_3 + 9p_2 + 11p_1 \right\} \dots \dots \dots (5)$$

$$M = P_1 x - p_1 \left(x - \frac{l}{12} \right) - p_2 \left(x - \frac{l}{4} \right) - \frac{3p_3}{l} \left(x - \frac{l}{3} \right)^2 \dots \dots (6)$$

And to render M a maximum, we find

$$x = \frac{l}{2} \left\{ 1 - \frac{3(p_2 - p_4) + p_1 - p_5}{36p_3} \right\} \dots \dots \dots (7)$$

The values of P_1 and x , substituted in equation (6), give the greatest moment, M , tending to rupture the ship.

(1) If $p_5 = p_1$, and $p_4 = p_2$, then equation (7) becomes $x = \frac{l}{2}$; that is, the greatest strain will be at the centre C .

And from equation (5) we find $P_1 = p_1 + p_2 + p_3$; and substituting in equation (6), we get

$$M = \frac{l}{12} (p_1 + 3p_2 + 5p_3) \dots \dots \dots (8)$$

(2) If $\frac{W}{2}$ be put for the sum of the pressures, p_1, p_2, p_3 , on each half of the ship, and let G_1 be the centre of gravity of these pressures, then

$$\left. \begin{aligned} M &= P_1 \times AC - \frac{W}{2} \times G_1 C = \frac{W}{2} \times AC - \frac{W}{2} \times G_1 C \\ &= \frac{W}{2} \times AG_1; \end{aligned} \right\} \dots \dots \dots (9)$$

that is, the moment tending to rupture the beam at the centre is equal to the load on one half of the ship multiplied by the distance of its centre of gravity from the extremity.

12. Now let us suppose that the ship is balanced upon its centre C (see fig. 4); then, in this case, the greatest strain will obviously be at the point of support C ; hence we have

$$M = p_1 \times DC + p_2 \times HC + p_3 \times \frac{1}{2} EC;$$

but

$$DC = \frac{5}{12} l, HC = \frac{3}{12} l, \text{ and } \frac{1}{2} EC = \frac{1}{12} l;$$

$$\therefore M = \frac{l}{12} (5p_1 + 3p_2 + p_3); \dots \dots \dots (10)$$

or proceeding as in equation (9), we get

$$M = \frac{W}{2} \times G_1 C, \text{ or } \frac{W}{2} \left(\frac{l}{2} - AG_1 \right) \dots \dots \dots (11)$$

Comparing this expression with equation (9), it will be observed that as the load is accumulated towards the centre of the ship, AG_1 will be greater than $G_1 C$, and therefore (9) will be greater than (11).

13. If the load be equally distributed, or $p_1 = p_2 = \&c. = \frac{W}{6}$, then $AG_1 = \frac{1}{2}$ of $\frac{l}{2} = \frac{l}{4}$, and equation (9) becomes

$$M = \frac{W}{2} \left(\frac{l}{4} \right) = \frac{Wl}{8}, \dots \dots \dots (12)$$

and from equation (11) we get

$$M = \frac{W}{2} \left(\frac{l}{2} - \frac{l}{4} \right) = \frac{Wl}{8} \dots \dots \dots (13)$$

where the results of equation (12) and (13) are the same; that is to say, the

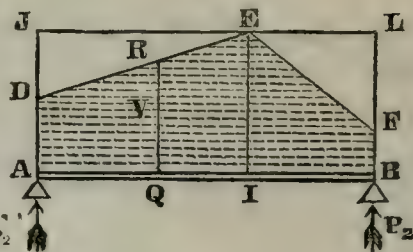
moments tending to rupture the ship, in the two positions, are the same when the load is uniformly distributed throughout its length.

14. When the load has the form of a trapezoidal figure ADEFB, to find the greatest moment tending to rupture the beam AB supported at its extremities.

Let $AB=l$, $AI=a$, $IB=a_1$, $EI=e$, $AD=b$, $BF=b_1$, $AQ=x$, μ =the weight of a unit of surface in the load.

Now, observing that the moment of the surface ADEFB is equal to the moment of the rectangle AJLB minus the sum of the moments of the triangles DJE and ELF, we find, after reduction,

Fig. 5.



$$P_1 = \frac{\mu}{6l} \left\{ 3el^2 - a(e-b)(2a+3a_1) - (e-b_1)a_1^2 \right\} \dots\dots (14)$$

When $a_1=a$, this expression becomes

$$P_1 = \frac{\mu a}{12} (6e+5b+b_1) \dots\dots\dots (15)$$

The trapezoid ADRQ being composed of the rectangle ADVQ and the triangle DVR, we have

$$\begin{aligned} M &= P_1 x - \mu b x \times \frac{x}{2} - \frac{x}{2} \times \frac{e-b}{a} \times x \times \mu \frac{1}{3} x \\ &= P_1 x - \frac{1}{2} \mu b x^2 - \frac{1}{6} \mu \frac{e-b}{a} x^3. \dots\dots\dots (16) \end{aligned}$$

Hence for the maximum value of M ,

$$\begin{aligned} \frac{dM}{dx} &= P_1 - \mu b x - \frac{\mu(e-b)}{2a} x^2 = 0; \\ \therefore x &= \frac{a}{e-b} \left\{ \sqrt{\frac{2(e-b)}{\mu a} P_1 + b^2 - b} \right\} \dots\dots\dots (17) \end{aligned}$$

which gives the point Q where the greatest strain takes place.

The values of P_1 and x being substituted in equation (16), we find the maximum value of M as required.

(1) When $a_1=a$, then P_1 is expressed by equation (15), and we get

$$x = \frac{a}{e-b} \left\{ \sqrt{\frac{1}{6}(e-b)(6e+5b+b_1) + b^2 - b} \right\} \dots\dots\dots (18)$$

Substituting these values in equation (16), we find the maximum moment required.

(2) When $b_1=b$ in the last equalities, we find $x=a$; that is, the greatest strain will take place in the centre of the beam; and from equation (16) and (15) we get

$$M = \frac{1}{6} \mu a^2 (2e+b) \dots\dots\dots (19)$$

SECTION III.

Strength, &c., of Beams.

15. The moment of the forces tending to rupture a beam being always equal to the moment of the forces resisting rupture, the symbol M may be

used to express either of these moments. It must be observed, therefore, that all the expressions hereafter given for M , the moment of rupture or the moment of flexure, as the case may be, are equal to the moment of the forces tending to break the beam.

16. Let h equal the distance of the upper edge of the section of rupture from the neutral axis passing through the centre of gravity of the section; h_1 the distance of the lower edge from the neutral axis; S = the resistance of the material, per square inch, to compression at the upper edge; S_1 = the resistance of the material, per square inch, to extension at the lower edge; and I_0 = the moment of inertia of the section about its centre of gravity; then

$$M = \frac{S}{h} \cdot I_0, \text{ or } \frac{S_1}{h_1} \cdot I_0. \dots\dots\dots (1)$$

The value of I_0 depends solely on the geometrical form of the transverse section of the beam.

17. The following values of I_0 for different sections of material will be found useful in calculating the transverse strength of a beam having a complex section, such as that of an iron ship.

(1) For a thin plate, AB , about any axis, NO , passing through its centre of gravity C ,

$$I_0 = \frac{1}{12} K l^2 \sin^2 \theta,$$

where K is the area of the section, and $l \sin \theta$ the projection of l , the length of the plate, upon the vertical or upon a line perpendicular to the axis.

(2) For a hollow rectangle,

$$I_0 = \frac{1}{12} (bd^3 - b_1 d_1^3),$$

where b = the breadth of the section, d = its depth, b_1 = the internal breadth, and d_1 = its internal depth.

(3) For an ellipsis about any axis NO passing through the centre C ,

$$I_0 = \frac{1}{4} K p^2,$$

where $2p = AB$, the vertical depth of the section when the major and minor axes are equal, $p = r$ the radius of the circle.

(4) For a hollow circle,

$$I_0 = \frac{K}{16} (d^2 + d_1^2),$$

where d and d_1 are the external and internal diameters respectively.

When the plate is thin, $I_0 = \frac{1}{8} K d^2$ very nearly, which also approximately expresses that of a hollow elliptical section, d being the vertical axis.

(5) When the depth of any surface is small as compared with its distance from the axis,

$$I = a \alpha^2 \text{ very nearly,}$$

where a = the area of the section, and α = the distance of its centre of gravity from the axis about which the moment of inertia is taken.

(6) The moment of inertia of a square is the same for all axes passing

Fig. 6.

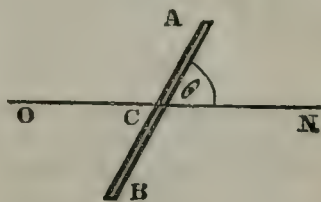
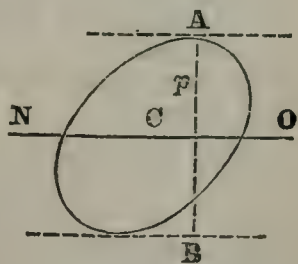


Fig. 7.



through the centre, whatever may be the inclination. Thus

$$I_0 = \frac{1}{12} l^4,$$

where l = the length of the side.

And for a square hollow girder of uniform thickness,

$$I_0 = \frac{1}{12} (l^4 - l_1^4),$$

where l_1 = the length of the interior side.

(7) For a parallelogram CEFG about any axis AB passing through the centre,

$$I_0 = \frac{1}{12} K \{ l^2 \sin^2 (\theta_1 + \theta) + e^2 \sin^2 \theta_1 \},$$

where $l = CG = EF$; $e = CE = GF$; K = area of parallelogram; θ = angle GCE, θ_1 = angle B, the angle which the side CE or CE produced makes with the axis of moments.

When $\theta = 90^\circ$, or the surface becomes a rectangle,

$$I_0 = \frac{1}{12} K \{ l^2 \cos^2 \theta_1 + e^2 \sin^2 \theta_1 \}.$$

(8) For angle-iron AMRFE about any axis NO,

$$I = \frac{1}{12} (l^4 - l_1^4) + l^2 \bar{x}^2 - l_1^2 \bar{x}_1^2,$$

where $l = AM = MR$, $l_1 = EF = FL$, $\bar{x}$, $\bar{x}_1$ = the distance of the centres of the squares MC and FC respectively from NO.

(9) If A and B be put for the moments of inertia of a surface about its two principal axes, perpendicular to each other respectively, then the moment of inertia of the surface about any axis passing through the centre will be

$$I_0 = A \cos^2 \theta_1 + B \sin^2 \theta_1,$$

where θ_1 is the inclination of the oblique axis to the principal axis corresponding to the moment of inertia A.

(10) For a plate RB in the form of a quadrant, about the axis NO parallel to the radius CB,

$$I = \frac{\pi}{16} \left\{ r^2 (r^2 + 4e^2) - r_1^2 (r_1^2 + 4e^2) \right\} + \frac{2}{3} e (r^3 - r_1^3),$$

where r is put for the external radius of the plate, r_1 for its internal radius, and e is put for the distance of the axis NO from the radius CB.

When the thickness of the plate is small as compared with its distance e from the axis, then

$$I = \frac{1}{4} K (r^2 + 4e^2) + \frac{2}{3} e (r^3 - r_1^3).$$

Fig. 8.

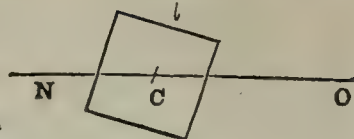


Fig. 9.

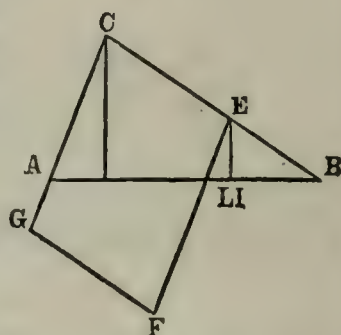


Fig. 10.

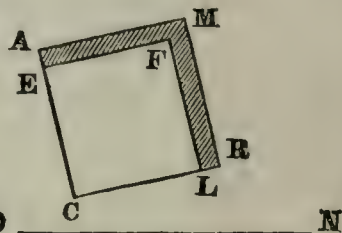
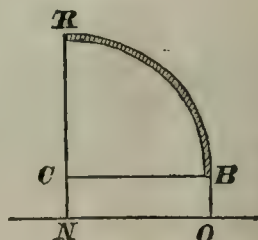


Fig. 11.



SECTION IV.

To find the Moment of a Complex Girder, such as an iron ship, composed of a series of parts.

18. Let $a_0, a_1, \dots, a_n$ represent the sectional areas of the portions com-

posing the transverse section of the beam; $\alpha_0, \alpha_1, \dots \alpha_n$ the distance of the centres of gravity of these areas respectively from the upper edge AB of the section; $Q_0, Q_1, \dots Q_n$ the moments of inertia of these areas respectively about their respective centres of gravity; h the distance of the neutral axis of the whole section from the upper edge.

For the neutral axis we have

$$h = \frac{\alpha_0 \alpha_0 + \alpha_1 \alpha_1 + \dots + \alpha_n \alpha_n}{\alpha_0 + \alpha_1 + \dots + \alpha_n} = \frac{1}{K} \Sigma \alpha_n^2 \dots \dots \dots (1)$$

The distance of the centre of gravity of the area α_n from the neutral axis is $(h - \alpha_n)$, and so on to the others; hence we find

$$I_0 = Q_0 + Q_1 + \dots Q_n + \alpha_0(h - \alpha_0)^2 + \alpha_1(h - \alpha_1)^2 + \dots + \alpha_n(h - \alpha_n)^2 \\ = \Sigma Q_n + \Sigma \alpha_n(h - \alpha_n)^2, \dots \dots \dots (2)$$

where it will be observed that $(h - \alpha_n)^2$ is always positive.

Hence we have the following general theorem:—

General Theorem I.—If the section of a compound girder be composed of a series of sectional areas, the moment of inertia of the whole section, about its neutral axis, is equal to the sum of the moments of inertia of the different sections about their respective centres of gravity added to the sum of all the areas multiplied respectively by the square of the distance of their centres of gravity from the neutral axis.

N.B.—It may happen that the moment of inertia Q_1 of some part of the section can be most readily found by referring at once to the neutral axis NO of the whole section; then, in this case, the value of Q_1 must be added to equation (2).

19. If Q_0, Q_1 be taken as the moments of inertia of the sectional areas which meet or pass through the line of the neutral axis, or which may have a considerable depth, as, for example, the side plates of a tubular girder; and supposing the other sectional areas to be accumulated toward the upper and lower parts of the section of the beam; then the depths of these sectional areas being small as compared with their respective distances from the neutral axis, $Q_2, \dots, Q_n$ may be neglected without incurring any considerable error;

$$\therefore I_0 = Q_0 + Q_1 + \Sigma \alpha_n(h - \alpha_n)^2. \dots \dots \dots (3)$$

And if Q_0, Q_1 be neglected, then

$$I_0 = \Sigma \alpha_n(h - \alpha_n)^2. \dots \dots \dots (4)$$

Hence we have the following general theorem:—

General Theorem II.—When the different depths of the sectional areas of a series of plates, forming a compound girder, are small as compared with the distance of their respective centres of gravity from the neutral axis, then the moment of inertia of the whole section is very nearly equal to the sum of all the areas multiplied respectively by the square of the distance of their centres of gravity from the neutral axis.

20. To determine the strength, &c., of a tubular beam, ABCD (fig. 12), composed of a series of cells AF, with angle-iron, at the top part, and of thick solid plates CD at the bottom part.

Here the section of the beam may be divided into three portions, viz. the cells at the top, the bottom plates, and the side plates.

For the position of the neutral axis NO we have by equation (1), art. 18,

$$h = \frac{1}{K}(a_0\alpha_0 + a_1\alpha_1 + a_2\alpha_2), \dots\dots\dots (1)$$

where a_0, a_1, a_2 are the areas of the material in the sides, in the top cells, and in the bottom plates respectively, and so on.

If $D=AC$, the depth of the beam, then $h_1=D-h$.

From equation (2), art. 18, we get

$$I_0 = Q_0 + Q_1 + Q_2 + a_0(h-\alpha_0)^2 + a_1(h-\alpha_1)^2 + a_2(h-\alpha_2)^2, \dots\dots\dots (2)$$

where Q_0 =the moment of inertia of the side plates about their centre of gravity, Q_1 that of the top cells, and Q_2 that of the bottom plates.

If the beam be loaded in the middle and supported at the ends, then $M=\frac{1}{4}Wl$, and

$$\begin{aligned} \frac{1}{4}Wl = M &= \frac{S}{h}I_0 \text{ or } \frac{S_1}{h_1}I_0; \\ \therefore W &= \frac{4SI_0}{hl} \text{ or } \frac{4S_1I_0}{h_1l}, \dots\dots\dots (3) \end{aligned}$$

which gives the load corresponding to any assumed value of S or S_1 . Conversely S or S_1 may be determined for any given load, W .

(1) The following is a more simple and practical method of calculating (approximately) the strength of these beams.

Putting a, a_1 for the areas of the top and bottom parts respectively, g, g_1 for the distance of their respective centres of gravity from NO, and $G=g+g_1$, neglecting the side plates, for the position of the neutral axis, we have

$$ag = a_1g_1. \dots\dots\dots (4)$$

And from *General Theorem II.*, art. 19, we get

$$\begin{aligned} I_0 &= ag^2 + a_1g_1^2 = ag(g+g_1) \text{ or } a_1g_1(g+g_1) \\ &= agG \text{ or } a_1g_1G; \dots\dots\dots (5) \end{aligned}$$

$$\begin{aligned} \therefore M &= \frac{S}{h}agG \text{ or } \frac{S_1}{h_1}a_1g_1G \\ &= SaD \times \frac{gG}{hD} \text{ or } S_1a_1D \times \frac{g_1G}{h_1D} \\ &= SaD \text{ or } S_1a_1D \text{ nearly}, \dots\dots\dots (6) \end{aligned}$$

taking $\frac{gG}{hD}$ and $\frac{g_1G}{h_1D}$ as constants, each being nearly equal to unity.

Here the strength varies as the top or bottom areas multiplied by the depth.

If K be put for the whole section, and taking $\frac{SgG}{hD} = \frac{S_1g_1G}{h_1D} = \text{a constant}$, we get

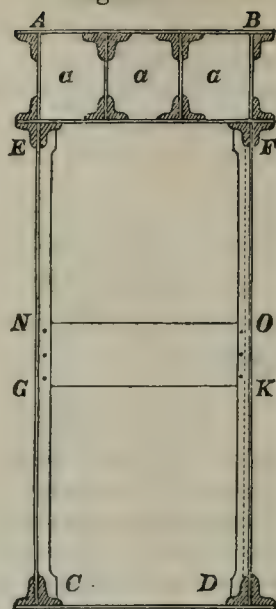
$$M = C(a+a_1)D = CKD. \dots\dots\dots (7)$$

Here the strength varies as the whole section multiplied by the depth.

When $M=\frac{1}{4}Wl$, we get

$$W = \frac{4SaD}{l} \text{ or } \frac{4S_1a_1D}{l}. \dots\dots\dots (8)$$

Fig. 12.



A similar formula may be derived for beams with double flanges.

From the experiments on the model Conway tube we find $S_1 = 16.5$ tons; hence we have

$$W = \frac{66a_1D}{l}, \dots\dots\dots (9)$$

which is the formula usually employed for calculating the strength of these beams; where W is expressed in tons, a_1 being the area of the bottom plate in inches, D the whole depth of the beam, and l the distance between the two supports expressed in the same units as D .

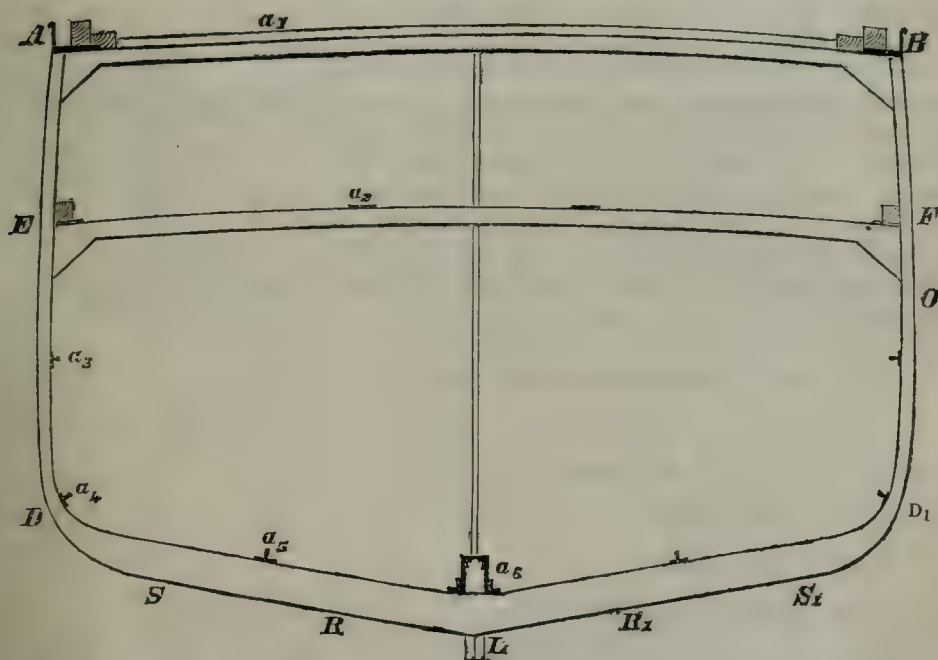
In cast-iron beams with double flanges, as derived from the experiments of the late Mr. Hodgkinson,

$$W = \frac{26a_1D}{l}. \dots\dots\dots (10)$$

Strength of an Iron Ship.

21. To determine the strength, &c., of an iron ship, the transverse section being represented in the annexed diagram, AB and EF the upper and lower decks, AD and BD_1 the sides down to the bilge, LR , RS , SD , &c. a series of plates, assumed to be straight, forming the bottom, and so on.

Fig. 13.



Having divided the section into a convenient number of parts, formulæ (1) and (2), art 18, give the most exact method of calculating the moment of inertia of the whole section; where the moment of inertia of each part about its centre of gravity must be determined, and so on. But the following method of calculation is more simple and sufficiently exact for all practical purposes.

Put a_1 for the area of the material in the upper deck; a_2 for that of the lower deck; a_3 for the lower hold stringers; a_4 for the bilge keelsons; a_5 for the sister keelsons; a_6 for the middle keelson; a_7 for the keel piece L ; a_8 for the plates LR , LR_1 ; a_9 for the plates RS , R_1S_1 ; a_{10} for the plates SD , S_1D_1 ;

α_0 for the side plates AD, BD₁ down to the top of bilge, d_0 being their depth; and so on, as before; the equations (1) and (3), art. 18, 19, will become

$$h = \frac{1}{K} \sum_0^{10} a_n \alpha_n, \dots\dots\dots (1)$$

$$I_0 = Q_0 + \sum_0^{10} \alpha_n (h - \alpha_n)^2 = \frac{1}{12} a_0 d_0^3 + \sum_0^{10} a_n (h - \alpha_n)^2, \dots\dots\dots (2)$$

where Q_0 is the moment of inertia of the side plates about their centre of gravity. It will be observed that $(h - \alpha_n)^2$ is always positive.

And we further have

$$M = \frac{S}{h} I_0 \text{ or } \frac{S_1}{h_1} I_0, \dots\dots\dots (3)$$

and

$$S = \frac{Mh}{I_0}, S_1 = \frac{Mh_1}{I_0}. \dots\dots\dots (4)$$

If the plates AE, ED have not the same thickness, then Q_1 of formula (3), art. 19, must be retained, and Q_0 and Q_1 calculated accordingly.

22. If a ship is supported at its extremities, and the load distributed as described in art. 10, then equations (6) or (2), according to circumstances, will give the value of M in the foregoing formulæ; or if the ship be supported at the centre, then equations (10) or (11), art. 12, will give the value of M , and so on to other cases.

To adopt a more summary though less accurate method of calculation, let AD represent the section of the material of an iron ship; the flange a_1 the section of the materials of the main deck; the flange a_2 the section of the lower deck; the flange a_3 the section of the bottom; a_0 the section of the material in the side plates or rib, d_0 being the depth, and so on, as before. In this case equations (1) and (2), art. 21, become

$$h = \frac{1}{K} (a_0 \alpha_0 + a_1 \alpha_1 + a_2 \alpha_2 + a_3 \alpha_3), \dots\dots\dots (5)$$

$$I_0 = \frac{1}{12} a_0 d_0^3 + a_0 (h - \alpha_0)^2 + a_1 (h - \alpha_1)^2 + a_2 (h - \alpha_2)^2 + a_3 (h - \alpha_3)^2. \dots\dots (6)$$

If we take $d_0 = D$, the whole depth of the section, $\alpha_2 = D$, $\alpha_0 = \frac{1}{2} D$, and $\alpha_1 = 0$, these formulæ become

$$h = \frac{1}{K} \left\{ \left(\frac{1}{2} a_0 + a_3 \right) D + a_2 \alpha_2 \right\}, \dots\dots\dots (7)$$

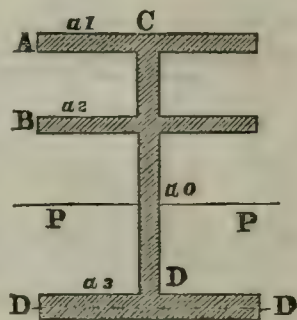
$$I_0 = a_0 \left\{ \frac{1}{12} D^3 + \left(h - \frac{1}{2} D \right)^2 \right\} + a_1 h^2 + a_2 (h - a_2)^2 + a_3 (h - D)^2. \dots\dots\dots (8)$$

When the depth and the amount of material in the transverse section are given, to determine the distribution of the material so that the beam may have the greatest strength.

23. The first and most important condition of maximum strength is, that the material should be accumulated, as far as practicable, at the upper and lower edges of the beam.

In tubular girders, where the material is accumulated at the upper and lower edges of the girder, the sectional areas at these parts should be in the inverse ratio of the ultimate resistances of the material in these parts respectively.

Fig. 14.



The results of experiments closely confirm the truth of this deduction. In wrought-iron girders, for example, the bottom section is about $\frac{5}{6}$ ths of the top section; and in cast-iron beams the section of the bottom flange is about $6\frac{1}{2}$ times that of the top flange, which is approximately, in the case of cast iron, the ratio of the resistance of compression to that of extension.

The next condition of maximum strength determines generally the relative amount of the material on each side of the neutral axis. The principle upon which this distribution of material depends is this: when the material at the upper edge of the beam is upon the point of yielding by compression, the material at the lower edge must at the same time be upon the point of yielding by extension; hence

$$\frac{S}{h} = \frac{S_1}{h_1}, \text{ or } \frac{S}{S_1} = \frac{h}{h_1}; \dots\dots\dots (1)$$

that is, *the distances of the neutral axis from the upper and lower edges of the beam should be in the ratio of the ultimate resistances of the material at these parts respectively.*

If $r = \frac{S}{S_1}$, and D = the whole depth of the beam, then

$$h = \frac{rD}{r+1} \dots (2), \text{ and } h_1 = \frac{D}{r+1} \dots\dots\dots (3)$$

In the case of wrought iron, $r = \frac{5}{6}$ nearly; that is, the ultimate resistance of wrought iron to compression is about $\frac{5}{6}$ of its ultimate resistance to extension.

24. To determine the area, a_1 , of the material in the transverse section of the upper deck (art. 22) so as to have a maximum strength with a given amount of material.

The strains on a ship afloat are somewhat different from the strains on an ordinary fixed girder; for it is found that the upper part of the transverse section of a ship when afloat is sometimes subjected to compression and at other times to that of extension. But of these two strains the former is generally the more violent. It will therefore be expedient, in calculating the distribution of the material in the section of an iron ship, to regard the upper portion of the section as that which is subjected to extension; and therefore in this case we should have

$$h = \frac{D}{r+1}.$$

Making this substitution in equation (7), art. 22, and putting $a_0 + a_1 + a_2 + a_3$ for K , we get

$$a_1 = \frac{r+1}{D} \left\{ \left(\frac{1}{2}a_0 + a_3 \right) D + a_2 \alpha_2 \right\} - (a_0 + a_2 + a_3). \dots\dots\dots (1)$$

If we assume $r=1$, then this expression becomes

$$a_1 = a_3 - a_2 + \frac{2a_2 \alpha_2}{D} \dots\dots\dots (2)$$

In one of our most approved iron ships, $a_0 = 440$ square inches, $a_2 = 156$, $a_3 = 490$, $D = 23\frac{1}{2}$ feet, $a_2 = 7\frac{1}{2}$ feet, required a_1 .

Substituting these values in equation (1), we find a_1 , or the area of the upper deck, to exceed 300 square inches. Now in this iron ship the equivalent area of the upper deck is only about 230 square inches; hence it appears that this portion of the ship should be about one-half stronger than it is, in order to have a proper distribution of the material.

It may not be practicable in all cases to construct iron ships with such a large section of iron at the upper deck; yet such should be the distribution of the material in the section in order to secure a maximum of strength with a given amount of material.

In the distribution of the material there is another consideration of some importance; and that is, that all bodies in the form of beams, whether hollow or solid, follow the same law as regards a transverse strain, viz. that in a beam uniformly loaded the strains are always greatest in the middle and progressively diminish to the points of support at either end. These facts are self-evident, and show in the case of an iron ship that the same thickness of plates is not required when working from the centre at midships to the stem and stern. In fact, they should taper or be reduced in thickness according to a certain ratio of their distances from the centre till they reach the extremes at each end. Theoretically this is true; but in practice we have to consider how much the thickness can be reduced without danger to the structure, and in general we may here observe that the reduction should not exceed *one-third* between the centres and the two extremes. Or, in other words, if we assume the strakes or sheathing plates of the bottom and round the bilge to the height of the interior floor, or one-fifth of the depth, to be seven-eighths of an inch, it then follows that their thicknesses may be safely and progressively reduced to five-eighths thick towards the bow and stern. The same reduction to five-eighths may be made from that point, one-fifth of the depth, to the neutral axis of transverse strains, or about halfway up the ship's side, when they should again increase to seven-eighths thick for the top strakes at the deck, on each side, where they have to perform the office of stringers and columns under the action of the two forces of tension and compression.

From these remarks it is obvious that a careful distribution of the material is a consideration of great importance in ship-building; and although it may be necessary in some constructions to deviate somewhat from the absolute rule, yet it is nevertheless essential that the law of strains should be carefully observed, and weak parts sufficiently guarded against.

SECTION V.

On the Penetration of Iron Armour-Plates by flat-faced tempered Steel Shot.

25. The experiments conducted at Shoeburyness seem to warrant the conclusion that, in firing at strong armour-plates with cast or wrought-iron shot, about one-half of the effect is lost in distorting or in breaking up the shot itself, and, further, that with steel shot of tough temper nearly the whole of the work stored in it is expended upon the plate.

Mr. Fairbairn's experiments on punching led to the following general laws relative to the resistance of iron plates to a force tending to rupture them:—

The diameter of the punch being constant, the pressure requisite to produce rupture varies, approximately, as the thickness of the plate.

When the thickness of the plate is constant, the pressure requisite to produce rupture varies, approximately, as the diameter of the punch.

And, generally, the pressure requisite to produce rupture varies as the thickness of the plate multiplied by the diameter of the punch, or, what amounts to the same thing, as the area of the shearing surface abraded in the process of punching; that is,

$$P \propto rt,$$

where P is the ultimate pressure in lbs., t the thickness of the plate in inches, and r the radius of the end of the punch.

View of portion of the S.W. Coast of Malta from the Sea, showing the relative positions of the strata, fossiliferous caverns, and Fault, with the alluvial deposit on the surface of the depressed land. (Fig. 1)



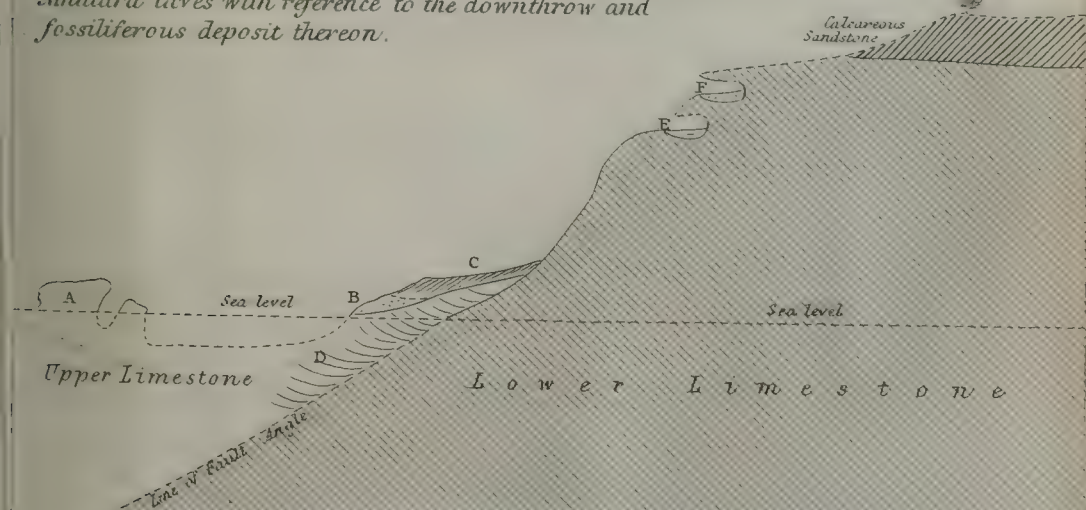
AAAA Lower Limestone
BBB. Upper Limestone

Miocene

Line of Fault marked by --- line and slickensides C.C. or D.D.

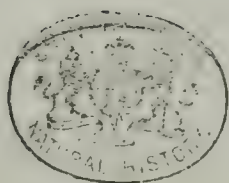
1, 2, 3. Positions of the three caves containing *cenure* or *Elephas Melitensis*, *Hippopotamus* &c. on cliff of A as recorded below. 4 Debris of the cave 1 Malak Cave
5 Alluvium and breccia containing remains of *E. Melitensis*. 6 Modern Alluvium covering 5 B Islet of Filfla,
composed of the Upper Limestone 1 The Malak Cave *Hippopotamus*, *Myocetus* &c. 2 Middle Cave *Myocetus Melitensis*
Arvicola Land Shells &c. 3 Mnajdra Cave *Elephas Melitensis*, *Myocetus* &c.

Section of the coast showing the positions of the Middle and Mnajdra caves with reference to the downthrow and fossiliferous deposit thereon.

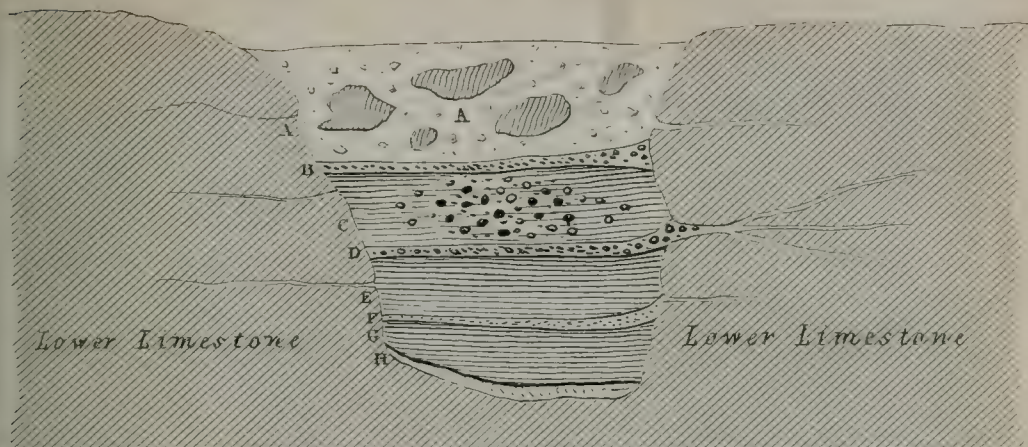


A. Islet of Filfla composed of the Upper Limestone
B. Breccia and red earth containing remains of *E. Melitensis*
C. Modern Alluvium covering B

D. Bent and contorted Strata consequent on the downthrow
E. Section of Middle Cave
F. Section of Mnajdra Cave

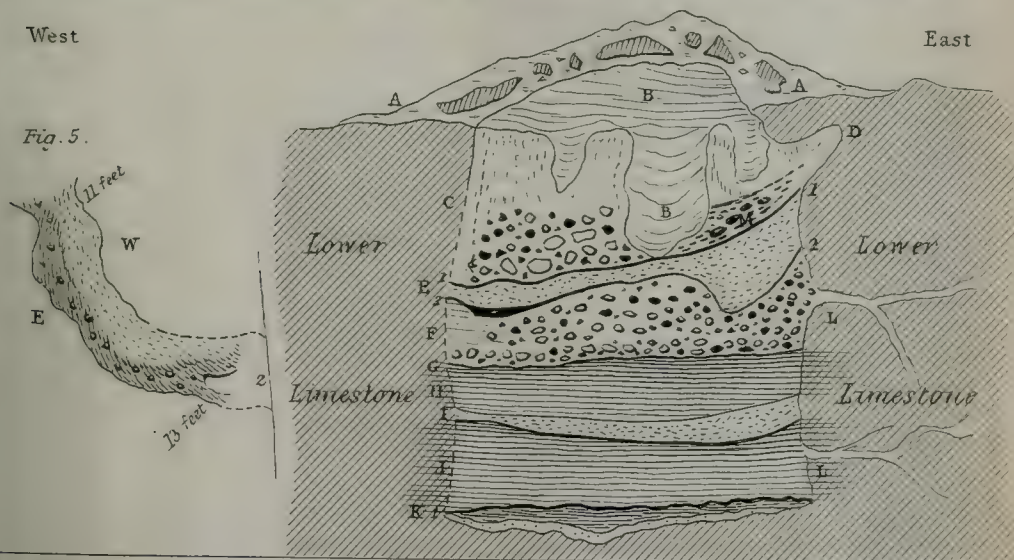


Section of Mnaidra Cave at its entrance (Fig. 3.)



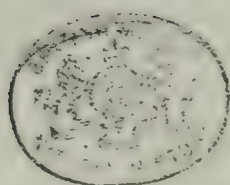
A, Superficial drift containing traces of *Myocetus Melitensis*, and masses of the parent rock—Lower Limestone—B, Shelf of Stalactite containing land shells, teeth and bones of the large Rodent *Myocetus Melitensis*, *Elephas Melitensis*, and Birds bones—C, Red clay and rounded stones mostly in the centre, with remains similar to B—D, A shelf of Stalactite and rounded stones at the bottom—E Red loam barren of organic remains—F, Yellow band, Ditto—G, Reddish black loam, Ditto—H White calcareous dripping with a black seam on the top, Ditto. The dark markings indicate where organic remains are found.

Section at the furthest limit of the excavation, May 10. 1865 (Fig. 4.)



A, Superficial drift with fragments of parent rock and remains of *Myocetus Melitensis*—B, Stalactite of roof—C, Red earth and rounded stones with organic remains, *Elephas*, *Myocetus*, Birds, &c.—E, Yellow band depending from D a gap in the roof with black seams 1 & 2. above & below it—F, Fossiliferous deposit similar to C—G, Hardened shelf of Stalagmite with rounded stones and organic remains, chiefly Birds—H, Red loam devoid of organic remains—I Band of yellow loam Ditto—J, Reddish black loam. Ditto—K, White calcareous Stalagmite with a black seam on its surface at x—L, Gaping horizontal fissures containing red earth—M, East corner where the left ramus of the lower jaw of *E. Melitensis* was found.

Fig 5, Ground plan of cave, dark lines show the extent & course of the fossiliferous band 2, The edge of a shelf of rock under which the cave is supposed to extend inwards.



Now the work U expended in the penetration of a plate by a force varying as the depth of penetration is expressed by the formula

$$U = \frac{1}{2}P \times \frac{1}{12}t; \\ \therefore U = Crt^2, \dots\dots\dots (1)$$

where the work requisite to penetrate a plate varies as the square of its thickness multiplied by the radius of the shot.

Substituting the value of the constant C , deduced from the experiments with ordnance, we get

$$U = 24400rt^2, \dots\dots\dots (2)$$

where $U = \frac{wv^2}{2g}$, the work in the projectile at the instant of impact.

Hence we have for the depth of penetration by a shot with a given weight, size, and velocity,

$$t = \sqrt{\frac{U}{24400r}} \dots\dots\dots (3)$$

From this formula it follows that a 100 lb. steel shot of tough temper, 6 inches diameter, with the velocity of 1200 feet per second, will completely perforate an armour-plate 5 inches in thickness. This result is fairly borne out by the results of experiments with ordnance.

If $3\frac{3}{4}$ inches be taken as the average radius of a shot, then formula (3) becomes

$$t = \frac{1}{300} \sqrt{U}, \dots\dots\dots (4)$$

which may be regarded as a rough approximation of the damaging effect of shot not differing widely from this dimension.

Maltese Caves.—Report on Mnaidra Cave.

By A. LEITH ADAMS, M.A., M.B., F.G.S.

1. THE strata composing the Maltese Islands belong to an early Miocene period; and attain a maximum height of about 720 feet above the sea-level. They consist, from above downwards, of the Upper Limestone, underlaid by beds of Sand, Marl, Calcareous Sandstone, and last of all, a rather compact and durable rock called the Lower Limestone. The latter attains its greatest height on the south and south-west coasts, reaching an elevation of 300 feet above the sea-level. Several cliffs of this bed contain natural caves, one of which, the subject of this Report, was discovered by me in 1863.

2. The Maltese strata are all more or less displaced by faults, whilst their exposed surfaces well attest the denuding effects of bygone atmospheric and aqueous agencies. This is very apparent in many situations; indeed the generally bare aspect of the islands, and the accumulations of soil and fragments of rocks in the fissures and hollows, together with depressions existing here and there, fully testify to the great changes which the area underwent during and subsequently to the period or periods when the remains of its post-tertiary fauna were being buried in those situations.

3. The alluvial deposits of the Maltese Islands consist—1st, of a calcareous red clay, containing peroxide of iron, and similar to that of many of the other islands and along the shores of the Mediterranean; and 2ndly, a blue marl, which is obtained from the degradation of the bed of that name, found *in situ* 1865.

in the higher parts of the islands. Intermediate varieties of both, consequent on the destruction of the rock formations, are also common, but it is in the deposits of one or other of the first two sorts that the remains of the extinct fossil fauna are usually found. These are generally intermixed with angular or rounded fragments of the rocks, forming compact breccias or conglomerates, which in the caves are often covered up by stalagmitic infiltrations and red earth; again, in fissures and hollows, large and loose accumulations of red soil, stones, and animal remains, huddled together in great disorder, display states of arrangement clearly referable to aqueous agency, and that of no common order and intensity.

4. Turning to the caverns, many may be said to be merely water-worn rents or fissures hollowed out at some period anterior to the introduction of the deposits and organic remains; for in many I have examined there existed communications with the surface by means of either perpendicular or lateral rents, through which their contents might have been introduced, or at least water in sufficient quantity to have rearranged any remains that were lying on the floors of the caves.

5. The subject of this Report I have named Mnaidra Cave*, after a remarkable ruin of that name in the immediate vicinity (supposed to have been constructed by the Phœnicians), and also to distinguish it from two other caves close by, one of which, viz. the "Middle Cave," is situated on a terrace-cliff within a few yards of the last and about 12 feet below it, whereas the third, called the "Hippopotamus" "or Malak Cave," opens on the same terrace cliff with the "Middle Cave," and is 200 feet distant from the Mnaidra Cave. The latter stands on the edge of a steep declivity overlooking the sea and above-mentioned terrace cliff, and is about 300 feet above the level of the former. Perhaps none of these caves maintain their original dimensions; for although at the time of their discovery each opened independently of the other, I have since been enabled, in the cases of both the "Malak" and "Middle Cave," to trace their lower deposits outwards from their entrances to the edge of the cliff, a distance of from 60 to 70 feet. It will be understood, therefore, that all these caves were situated close together on the side of a limestone cliff which faces the sea on the south-west coast of the island of Malta.

6. Nowhere in any of the islands forming the Maltese group is there a better illustration of the disturbances that have brought about the present insular condition of this area than at the point (represented in Plate II.); for along the base of the cliff there runs a fault by which the Upper Limestone of the series had been let down several hundred feet, and is now submerged, excepting a narrow belt that fringes the coast and spreads out into a stony flat westwards, whilst three miles out at sea the islet of Filfla forms its "outlier." On the surface of the depressed fragment, and washed by the waves, are masses of alluvial deposit and breccia formed of red earth, angular and partially rounded stones, of not only the parent rock, but also the Calcareous Sandstone and Lower Limestone, besides small portions of a *black limestone* rock, nowhere found *in situ* in the islands. These superficial deposits run up the incline towards the "line of fault," and are to all appearance the "talus" or washings of the slope above the caves. From among this mass of breccia and loose red earth and stones, my learned friend Dr. Errington, Archbishop of Trebizond, assisted me in removing the upper jaw and teeth of the "Pigmy

* 'Mnaidra' in Arabic means a "sheepfold," from the fancied resemblance this megalithic circle presents to a "sheep or cattle pen."

Elephant" (*Elephas melitensis*), which were found jammed between large blocks of limestone; their chipped and fractured condition, together with that of subsequent teeth and bones found in the same situation, clearly testify to the rough usage they had sustained from having been rolled along with stones and earth. The point therefore where the above remains were discovered was almost directly below the caves, and within a few feet of the sea-level. It is apparent, moreover, that the remains were deposited at a time when the depression was either taking place, or at least when it was below the level of the caves, else how could the fragments of the Lower Limestone have found their way into the deposit, seeing that the caves are situated at or about the uppermost limit of the Lower Limestone bed?

7. Before proceeding to give an account of the deposits of the Mnaidra Cave, it appears to me requisite that I should describe the chief particulars in connexion with the contents of the two other caves in its immediate vicinity, in order that the members of the Association may fully realize all the phenomena presented by the former. This I shall now do as briefly as possible.

8. The Malak Cave was discovered in 1858, but its outlet was destroyed and deposits disturbed, and the greater portion of them removed before any geologist examined it. The quarrymen who found it stated to me that it formed a simple excavation of an oval shape, and had a small opening looking on the afore-mentioned terrace-cliff. Its roof was seemingly entire (but that has not been proved). On its floor there was a hard conglomerate formed of light blue and red clays, intermixed with very rounded and water-worn stones, belonging to the parent rock *only*. Throughout this deposit, in great disorder, were strewn teeth and bones of two species of Hippopotamus, together with a few bones of large birds. One solitary lower molar of the Pigmy Elephant was found by me among the débris. It was very much worn, and adhered to the rounded pebble with which it had doubtless been rolled. This is the only instance I know where the Pigmy Elephant's remains have been found in connexion with the Hippopotamus. Not allowing for what had been removed by visitors and lost or destroyed, I counted the straight tusks of no less than thirty Hippopotami among the débris and in public and private collections, all I may add, procured from a deposit not exceeding a few yards in circumference, and certainly not more than three feet in thickness. No traces of gnawing were noticed on any of the remains I have examined, but many teeth and bones bore signal marks of having been much rolled. I may here state that in another deposit of Hippopotamus remains, found many years since at the entrance of the Melleha Valley, at the N.E. side of Malta (possibly also in a cave), they presented the exact appearances disclosed by those from Malak (*i. e.* both as to the nature of the deposit and condition of the remains). Upon the top of the Hippopotamus remains of the Malak was a stalagmite sparsely mixed with red and blue clays, where abundant remains of the Gigantic Dormouse (*Myoxus melitensis*) had been gradually introduced during the period that the cave was also being filled by calcareous drippings and soil. The bones of this rodent were also much broken and mixed in great disorder; teeth and jaws predominating, and just as I have seen the bones and teeth of the Egyptian Jerboa strewing the bottoms of caves in that country, after having been ejected in pellets from the craw of the Horned Owl (*Strix ascalaphus*). So much for the Malak Cave, which, as regards the order and nature of its organic remains and deposits on its floor, differed entirely from the Middle and Mnaidra Caves.

9. The deposits of the Middle and also the Mnaidra Cave were very similar. On their floors at the entrances were found the usual white calcareous

dripping with a black seam on its top, resembling coffee-grounds, and possibly chiefly consisting of the droppings of Bats. Over this deposit there lay three feet of a reddish black loam, much hardened here and there by stalagmitic infiltrations; and over this a seam of yellow earth, from half an inch to three inches in thickness, preceded* by a bed of a brick-red clay, averaging from 3 to 4 feet, and also interspersed with shelves and hardened masses of dripping.

So far, as regards Mnaidra Cave, not a trace of organic remains was visible; and, excepting in the Middle Cave, two teeth (much worn) of the Miocene Shark (*Carcharodon megalodon*) (a fossil found in the calcareous sandstone overlying that in which the cave existed, and possibly washed out of it), also in the brick-red clay a jaw of *Arvicola*, closely allied, if not identical with, *A. pratensis*, and frog's bones, both caves seem so far to have been filled up at the same time, and subjected to exactly the same influences. The Middle Cave continued to receive red earth slowly until within 6 feet of its roof, where a shelf of stalactite, containing abundance of recent land shells, bones, and teeth of the Gigantic Dormouse, marked a period of prolonged tranquillity, which was again broken by an influx of red earth to within 3 feet of the roof, when the stalagmite filled it up. There was no appearance of fissure on the roof of this cave, but it had many lateral rents; I did not, however, penetrate beyond a few yards on account of the great difficulty in working the deposits; I could see, however, that at no period in the history of the filling up of this cave was there any evidence of a large body of water having passed down it.

Turning back to Mnaidra Cave, it was now very clear that a decided change had taken place in the mode and nature of its deposits; for on the afore-mentioned shelf of stalagmite, and about halfway up, were rounded water-worn pebbles, interspersed among the red earth and calcareous infiltrations. Here were found many fragments and a few entire teeth of the Elephant, together with abundant remains of birds' bones of large dimensions, and teeth and bones of *Myoxus melitensis*. As the adit was being pushed inwards the fossiliferous deposit increased from 4 to 6 feet in thickness, and ran along the eastern wall, where it changed to a blue and red clay in nodules, whilst here and there depended masses of stalactite and dripping, in which were also found many Elephant's teeth and bones, associated with land snails of such species as *Helix aspersa*, *H. candidissima*, *H. vermiculata*, *H. aperta*, *Bulimus decollatus*, *Clausilia syracusana*, &c. As the tunnelling proceeded inwards another yellow seam began to appear about 4 feet from the bottom of the fossiliferous stratum, and to increase in depth until at the distance of from about 45 feet from the entrance it suddenly deepened and ran towards a depression on each side, and near the roof of the cave, where it measured $4\frac{1}{2}$ feet in thickness. It was composed entirely of the same ochre-yellow earth as the underlying stratum before mentioned, and like it was totally devoid of organic remains; moreover, from the manner in which it rose towards the opening on the side, there can be little doubt that it had been either partially or wholly introduced into the cave through the above opening. Although no alluvial deposit of the same description now exists in the surrounding area, there is every likelihood that it was obtained from the breaking up of the yellow variety of the calcareous sandstone, which has been entirely denuded from the surfaces around the cave, and for a little distance inland. On this yellow band lay another black seam, which thinned out on

* [The author probably means 'succeeded.'—G. Busk.]

elevated parts of the floor, but was several inches in thickness in the hollows. Large pillars of stalactite depended from the roof, and one central mass at the furthest limits of the adit, with its lower end resting on the black seam, seemed to divide the cave into two parts. On the eastern side of this pillar there was a deposit of black earth lying on the seam, through which ran a stratum of organic remains fully a foot in depth, rising upward towards the above-mentioned gap on the side of the cave near the roof. In this corner, and on a surface not 2 feet square, lay the left ramus of the lower jaw and tooth of a young Pigmy Elephant with several detached teeth, one cervical and six dorsal vertebræ of the animal, besides bats' bones, and bones and skulls of large water birds, and a vast assemblage of the remains of the Dormouse, together with very perfect specimens of land shells, all huddled together among minute fragments and splinters of bones. Both the deposit and organic remains in this side of the cave showed clearly that they had been enveloped by the slow introduction of the black loam, which was soon hardened by calcareous drippings, in fact that the pillar of stalactite here divided the cave into a wet and dry side (Plate III. fig. 4). On the western or wet side of the pillar very different causes had evidently been at work. The soil there was loose and mixed with the rounded pebbles of calcareous sandstone, only the latter were larger than any I had met with before, but like them they were nearly all hardened by calcareous infiltrations. Among the stones and clay numerous teeth and fragments of tusks and heads of bones of the Elephant were found. The organic remains seemed most abundant near the bottom of this fossiliferous deposit, which varied from 6 to 7 feet in thickness, and from 5 to 6 feet in breadth; but fragments of bones and plaits of teeth were met with even on the upper limits of the stratum close to the stalactite of the roof, which was upwards of 3 feet in thickness.

Such was the sequence of the various deposits in the Mnaidra Cave from below upwards, and for the distance of 54 feet inwards to the limits of my excavations; and how much further remains to be seen, as from the great heat of the weather and the Association's grant being expended, I have been obliged to defer any further researches until the return of the cold months, when I propose tracing the fossiliferous stratum to its limits. The Mnaidra Cave at its entrance measured 22 feet in height, and about 11 feet in breadth, when it gradually expanded and contracted, expanding a second time at the termination of the excavation, where its height was about the same as at the entrance, and breadth fully 13 feet. The sides of the cave were smooth, excepting where horizontal fissures formed gaping rents, into which the fossiliferous deposits had been washed, and much water and the finer portion of the clay introduced. The entire roof of this cave had evidently been cleared away from the entrance to the limits of the explorations, leaving merely the stalactite, and here and there a portion of the parent rock, the interstices being filled with soil drifted from the slope above, and composed of red earth and disintegrated fragments of the rock surfaces around. In this deposit I found remains of the great Dormouse, which I had previously met with in the stalactite on the roofs of other caves and superficial deposits in other situations in the island, all leading towards the belief that the above-named rodent may have lived on the area up to comparatively modern times.

10. With reference to the organic remains in this cave, it will readily be surmised, from what has been already stated, that the most prominent belonged to *Elephas melitensis* and *Myoxus melitensis*, just as the Hippopotamus

and the latter predominated in the neighbouring cave, with this exception, that in no instance were the remains of the rodent found in connexion with the Hippopotamus, whereas they were always intimately associated with bones and teeth of the Proboscidian, and not only in this cave, but in several other localities in the island.

11. Of the teeth of the Pigmy Elephant, either entire or in fragments, and guessing what were destroyed by the workmen to be equal to one half, I surmise that the remains of upwards of fifty old and young Elephants were brought to light during the late excavations in Mnaidra Cave. They include individuals of all ages, from the calf to the adult. Many teeth were in good states of preservation, others were much decayed and broken, especially the "true molars." The large bones were nearly all reduced to fragments but vertebræ and feet bones were usually entire. Many articulating surfaces of bones had their outer tables removed, and were firmly encrusted with stalactite, especially the specimens lying on a black seam and among the rounded freestones. It was clear, however, that they could not have been conveyed for any very long distance, as will appear from the specimens I have forwarded for the inspection of the members of the Association. Among the remains were found certain foot bones not referable, apparently, to this species, and at present undetermined; these I forwarded in another collection, now, I believe, in Mr. Busk's charge*.

12. The remains next in the order of frequency, and even, perhaps, more abundant than the last, were those of the Gigantic Dormouse (*Myoxus Melitensis*). The number of bones of this rodent brought to light during our excavations was almost beyond conception. They embraced all ages, and were strewn about in great disorder, but were far more entire than any of the others, or than those I have referred to in connexion with the Malak Cave; so much was this the case that I had seldom much difficulty in removing the greater part of skeletons, which enabled me to determine the relative dimensions of the animal with accuracy. For example, the total length of the skull, taken from many specimens, averaged in the adult from 2·3 to 2·5 inches; length of the humerus 1·6 inches; length of femur 2·2. The hind foot from the extremity of the calcaneum to the tip of the last phalanx of the middle toe measured 0·7 inch.

13. The avifauna of this cave embraced numerous remains of birds of various species, differing considerably in dimensions. Some of very large size were evidently water-birds. The collection I have forwarded for study†.

14. The Mollusca include the majority of the land-shells at present met with in the islands. The following have been identified by the late lamented Mr. S. P. Woodward:—

Helix aspersa.

„ *vermiculata*.

„ *candidissima*.

„ *aperta*.

Helix striata.

Bulimus acutus.

Cyclostoma —?

Clausilia syracusana.

The shells were found in such excellent states of preservation in the "Middle Cave," and with the rodent's remains in the "Malak," also with the jaw

* [So far as I have been able to determine these bones, they all appear to belong to one or other of the small Elephants.—G. B.]

† [These bones have been subjected to the inspection of Mr. W. K. Parker, who has detected among them many remains of the Gigantic Swan, which he had already observed in the collection of Fossils from Zebbug brought by Captain Spratt.—G. B.]

and bones of the Elephant in the corner east of the pillar of stalactite in "Mnaidra Cave," as to lead to a belief that they had crawled in and had been enveloped during the gradual filling up of the caves.

15. From the evidences here adduced and other proofs too lengthy in detail for this Report, it would appear that the lowermost deposits and organic remains of the Malak Cave were not deposited at exactly the same time with those of the other two in the vicinity. Its clayey bottom and conglomerate, formed solely of water-worn portions of the parent rock, seemed to indicate that the cave had at one time opened on the side of a river or lake, which occasionally washed its floor, whereas the lower deposits of both the Middle and Mnaidra caves show clearly that they were gradually filled by red earth and dripping from the roofs and sides, until some change in the physical condition of the surrounding area caused the roof of the Mnaidra Cave to be in great part removed, when bodies of water either swept the organic remains into the cave, and beyond it into the breccias and deposits, forming below on the sinking portion, or else disturbed and rearranged whatever remains may have been lying on the floor of the cave on the western side of the pillar of stalactite, leaving the remains on the east side unaffected. This, however, will become more evident when the fossiliferous deposit has been worked out, which I am of opinion ought to be done, not only with the view of ascertaining that point, but in hopes of finding new forms, and especially remains of the carnivorous quadrupeds which undoubtedly roamed over the area at the same period with the River-horse and Elephant, as the bones found by Captain Spratt and others in the cave of Zebbug clearly show. Every relic, of course, with reference to this point must be interesting; I therefore take the liberty of forwarding the lower jaw, femur, and tibia, appearing to belong to the "Common Weasel" (*Mustela vulgaris*), removed by me from a mass of clay that had been excavated from the deposit on the floor of the Zebbug Cave, where abundant remains of *Elephas melitensis*, &c., were discovered by Captain Spratt in 1859. It is the same locality described by that gentleman and the late Dr. Falconer at the Cambridge Meeting of the British Association in 1862.

16. Taking into consideration all the facts and probabilities furnished by careful examination of the Maltese caves, fissures and alluvial deposits, and the physical aspects of the various localities, I think there can be little doubt that at a late geological epoch in the history of the Maltese islands large bodies of water flowed over, at least, the greater part of the island of Malta, washing whatever soil or organic remains then happened to be lying on the surface into gaps, hollows, and depressions. No sea-shells have hitherto been met with in the soils and superficial deposits to indicate that the islands had been submerged and reelevated; on the contrary, from all appearances the last movement to which these islands were subject was a downward one. Unless, therefore, we suppose the giving way of lake barriers, divergence of rivers or streams, or the agencies of violent floods and freshets during changes consequent on oscillations of level, I see no other way of accounting for the phenomena represented by the above deposits and the fossil remains. In fact, I opine much the same conditions existed in Malta during the period of the fossiliferous deposits in Mnaidra Cave and others as obtained at Gibraltar when the "Genista" Cave was receiving its Pachydermata and other quadrupeds.

Report of the Gun-cotton Committee, consisting of WILLIAM FAIRBAIRN, LL.D., F.R.S., JOSEPH WHITWORTH, LL.D., F.R.S., JAMES NASMYTH, C.E., F.R.A.S., J. SCOTT RUSSELL, C.E., F.R.S., JOHN ANDERSON, C.E., Sir WILLIAM G. ARMSTRONG, C.B., LL.D., F.R.S., Dr. GLADSTONE, F.R.S., Prof. W. A. MILLER, M.D., F.R.S., Prof. FRANKLAND, F.R.S., and F. A. ABEL, F.R.S.

AFTER the report presented by this Committee at the Newcastle Meeting two years ago, the British Association, through a deputation headed by General Sabine, drew the attention of the Minister for War to the probable usefulness of Gun-cotton. In January 1864, the Government appointed a Committee to investigate the subject in all its bearings. This Committee consists of General Sabine as President, General Hay, Captain Brandreth, R.N., Commander Liddell, R.N., Colonel Boxer, R.A., Colonel Lovell, R.E., F. A. Abel, Esq., T. Sopwith, Esq., Professor W. A. Miller, Professor G. G. Stokes, and Dr. J. H. Gladstone, with Major Miller, R.A., as Secretary; representing thus the army, the navy, military and civil engineering, as well as chemical and physical science, and comprising three of the members of the British Association Gun-cotton Committee. Experiments on an extensive scale, and in a systematic manner, have been carried on by this Government Committee, and are still in progress; but no report has yet been published. Until that report is made, your Committee have suspended their labours.

On the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham. By A. FOLLETT OSLER, F.R.S.

[A communication ordered to be printed among the Reports.]

ANEMOMETRICAL observations having been taken hourly with considerable accuracy for several years, and those at Wrottesley, Liverpool, and Birmingham having been recorded on exactly the same principle (originally commenced by Mr. Hartnup in 1852), I was desirous of tabulating the results from those stations on a plan which I thought might prove of some value in extending our knowledge of the motion of the air in these latitudes, and possibly of developing some further laws bearing on that subject. Having observed that the hourly records of certain currents obtained from the integrating anemometer seemed to exhibit some peculiar features different from those I had obtained from the registration of the *force* of the wind, I wished, in the first place, to carry out some investigations on the horary variations by taking out the amount of horizontal motion instead of the force; the records of Dr. Robinson's integrating instrument have therefore been arranged in conjunction with those of time and direction, these registers being peculiarly suited for accurate tabulation, much more so than those of the force, which are most available for examining storms and sudden changes and marked variations in the aerial currents.

Besides these hourly results, I desired to investigate the records of the daily variations in the atmospheric currents throughout the year, with a view of ascertaining whether indications of any laws could be detected respecting their periodicity and amount.

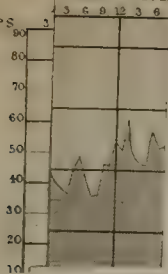
Accordingly I applied to Lord Wrottesley, who most kindly placed the whole of the valuable anemometrical records taken at his observatory at my

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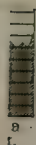
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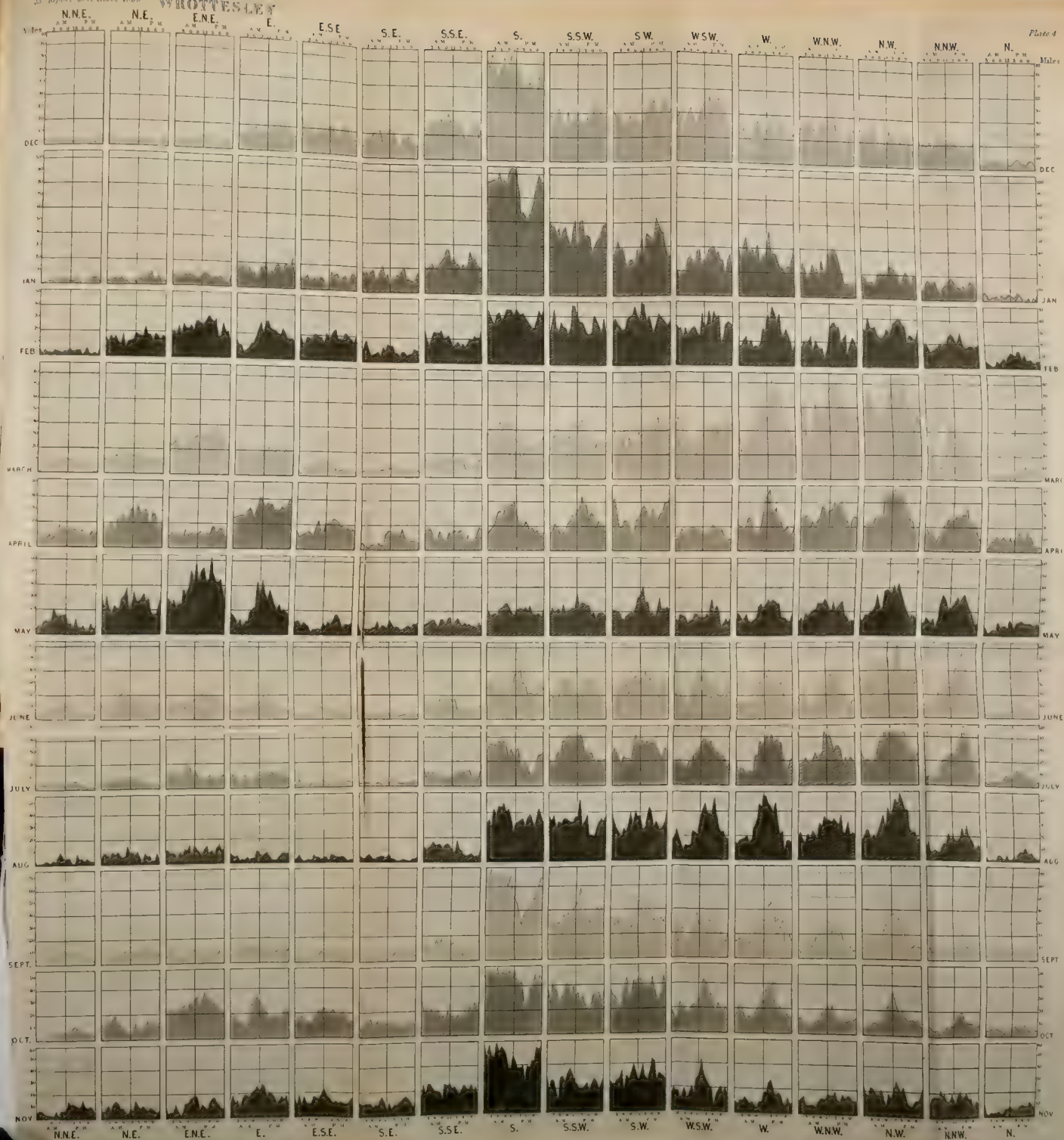
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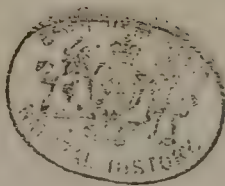
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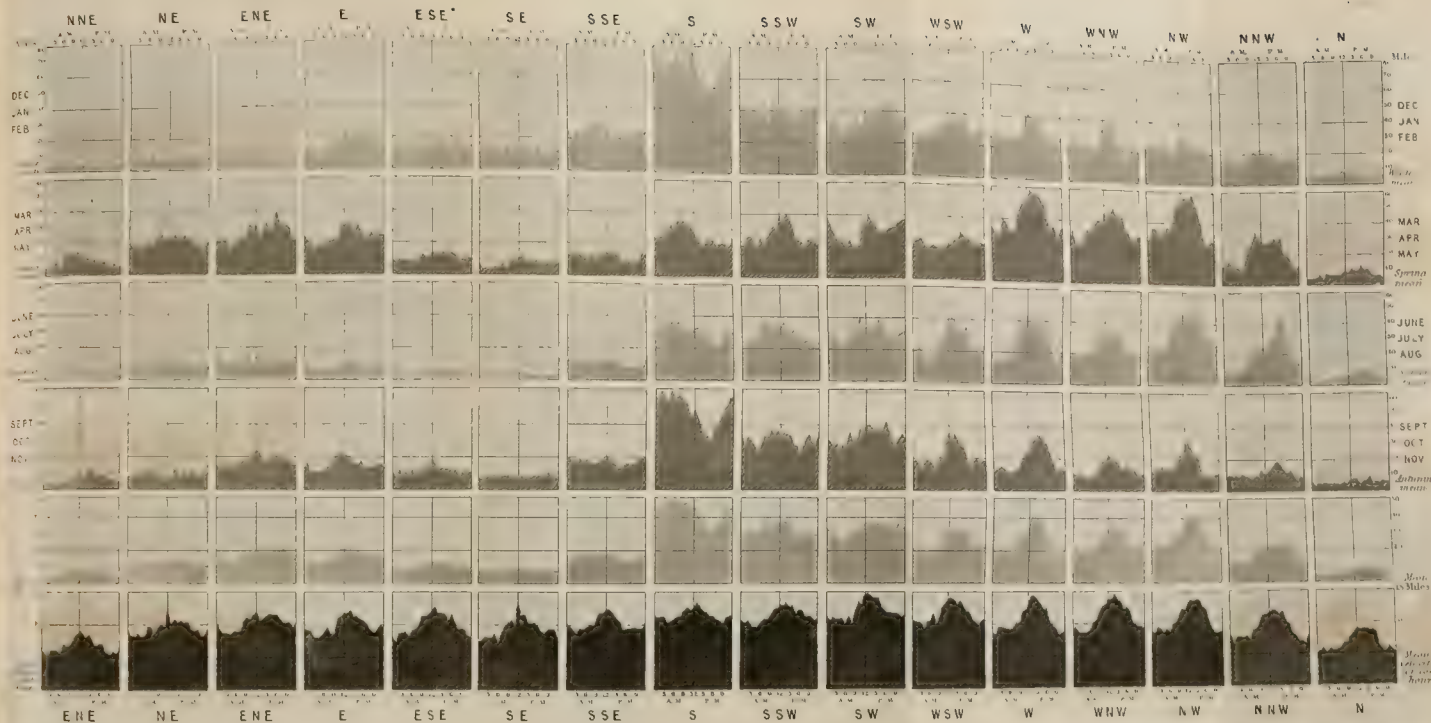
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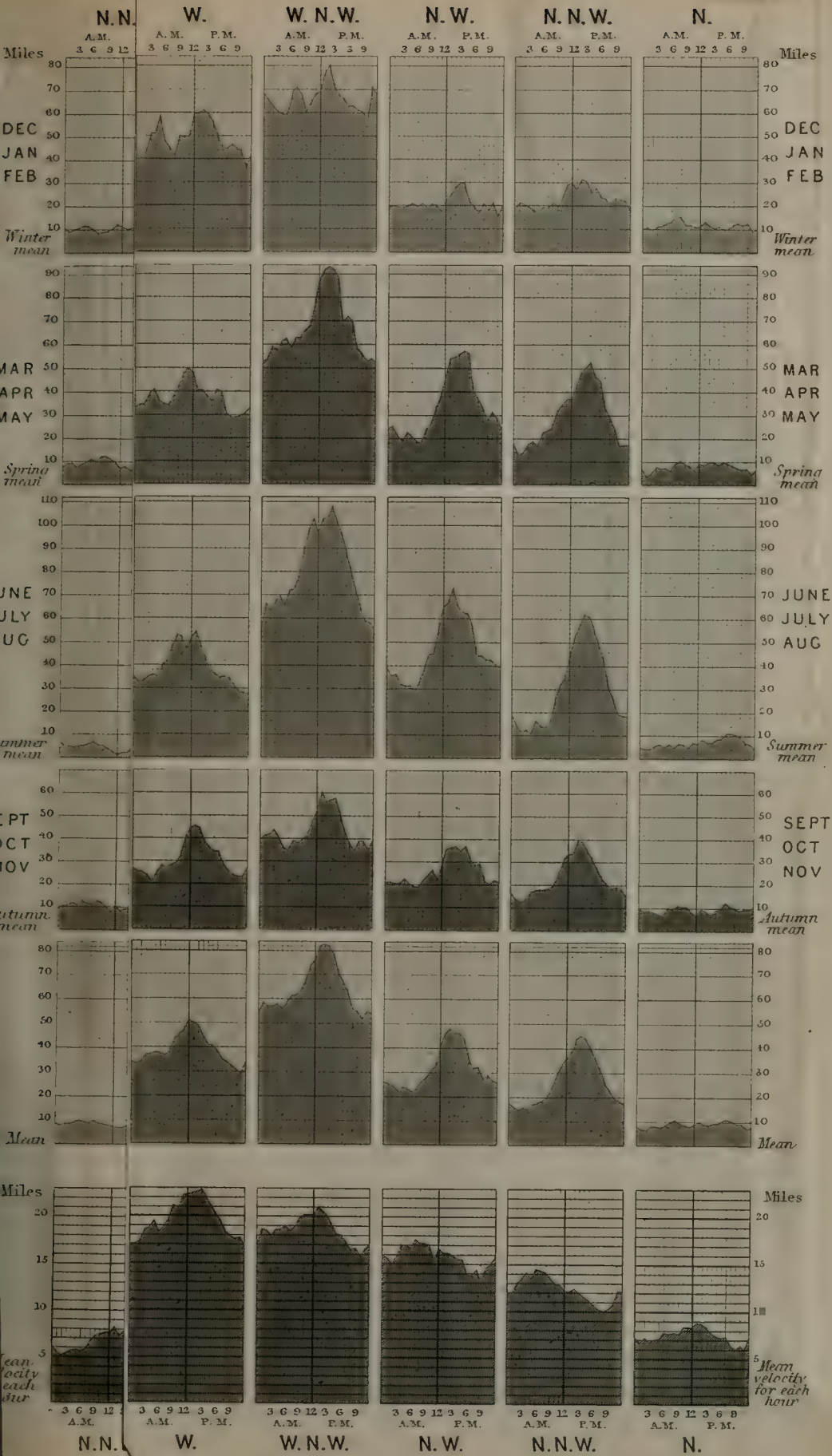
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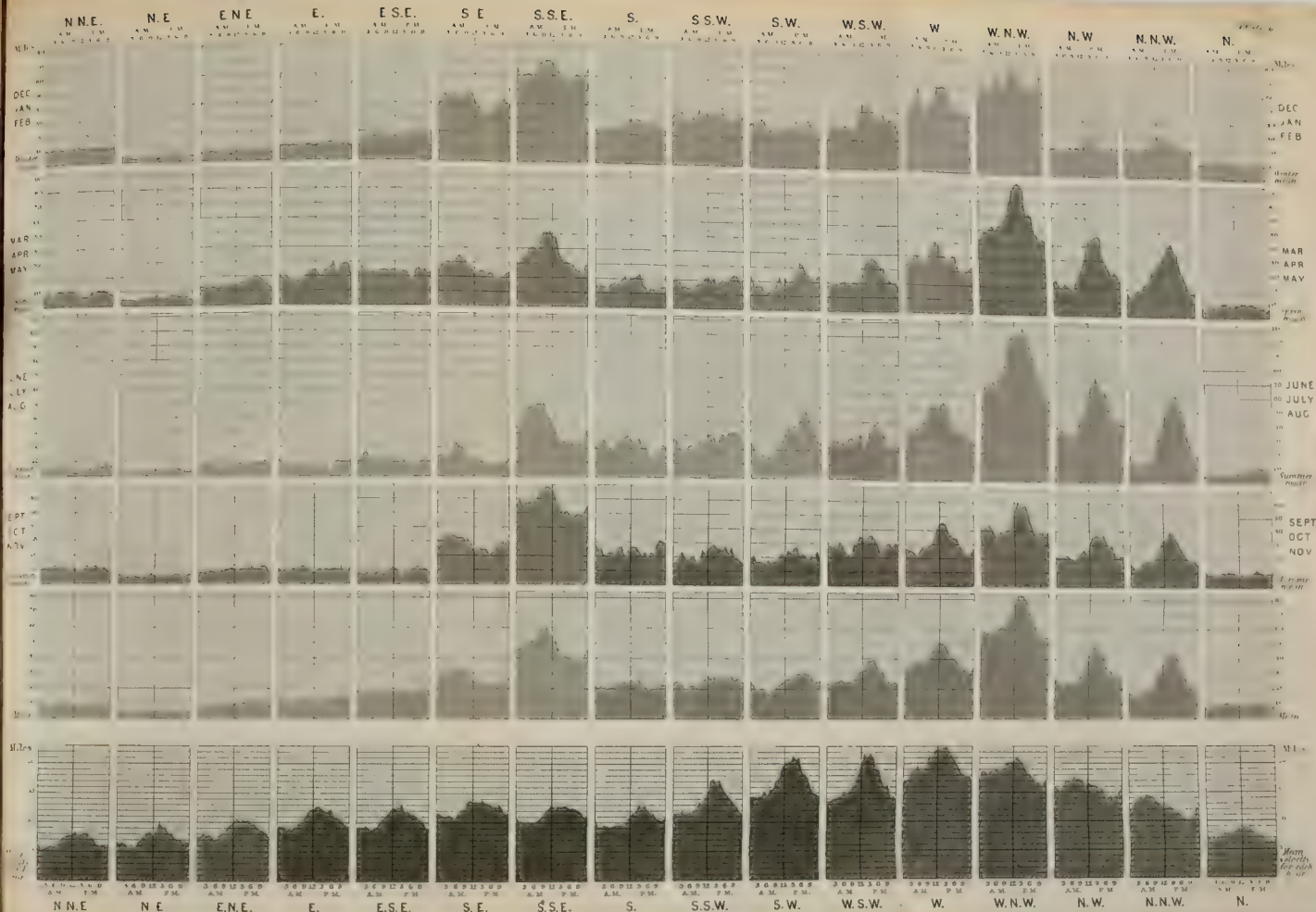


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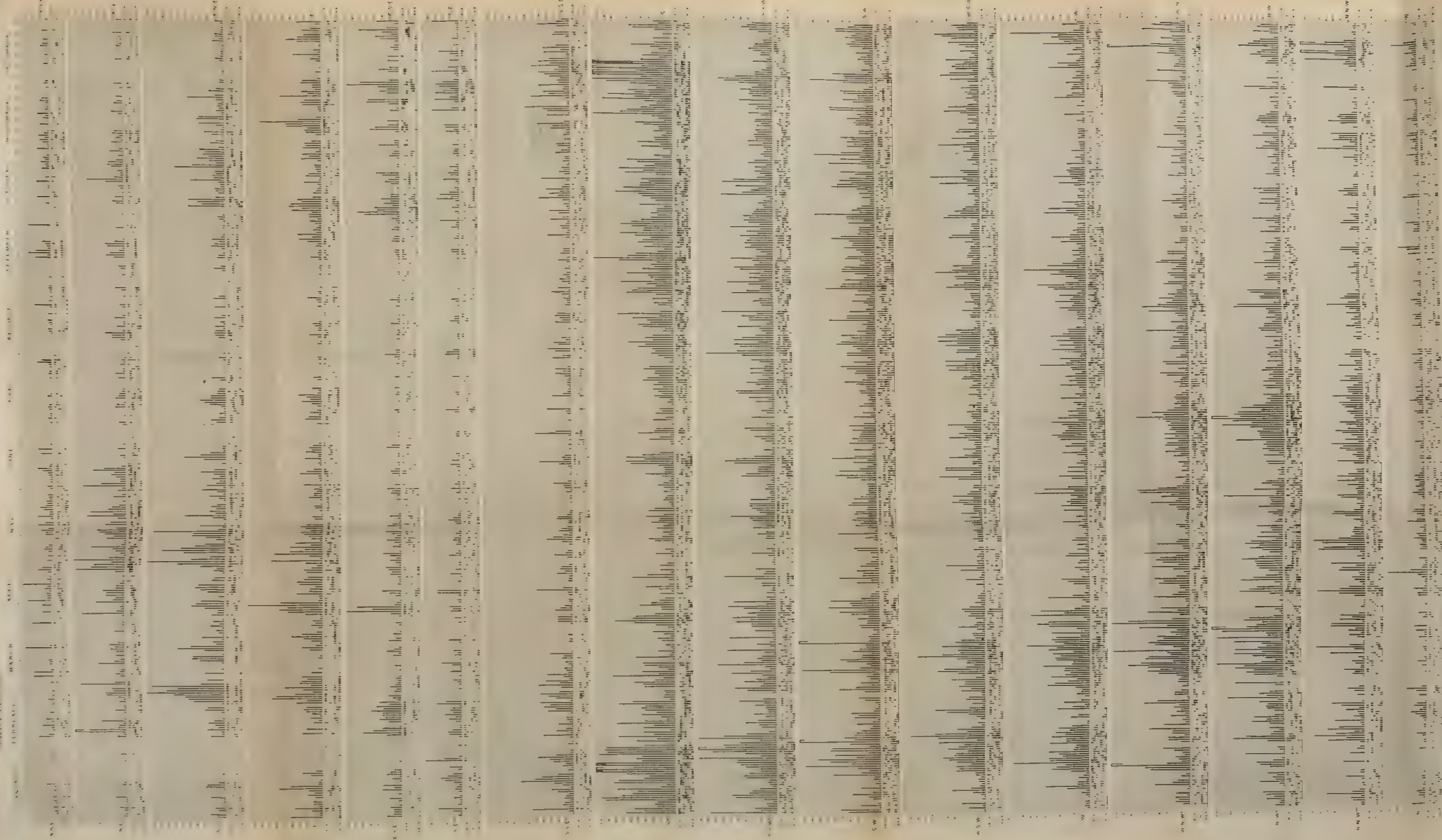
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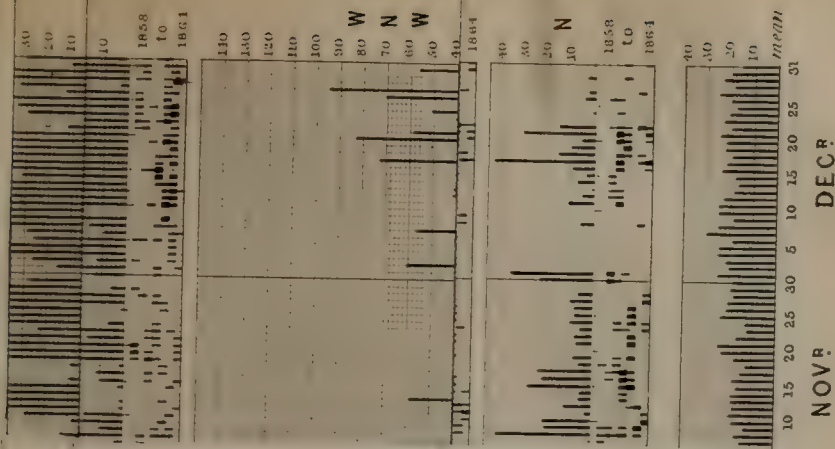
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disposal; my friend Mr. Hartnup did the same, and furthermore aided me very greatly by allowing his assistants to tabulate, in the manner I required, the observations of the direction and horizontal motion of the air as recorded at the Liverpool observatory. I have worked out the Birmingham observations on the same plan.

To commence with the horary variations. These extend over a period of nearly eight years at Wrottesley and thirteen years at Liverpool. The amount of motion of each wind for each of sixteen points of the compass is taken note of for every hour, from the daily records, and tabulated for every month. Commencing with the N.N.E. wind, the number of miles of air from this point that passed between midnight and one o'clock in the morning during the month of January in each year is tabulated; next between one and two o'clock, and so on through the twenty-four hours of the day. February is then treated in the same way, and thus through every month in the year, for each of the sixteen points of the compass, as shown in Table I., which is given as an example, exhibiting the amount of motion and duration of the south wind during each hour in December for each year.

From the mean of the seven years thus obtained, the monthly curves of horizontal motion for each hour at Wrottesley are projected. See Plate IV. The means of the separate months are also combined so as to obtain averages for the seasons and the whole year. In Table II. an example of this is given in the horary variations in the S.E. wind at Liverpool.

Plate V. exhibits the curves projected from tables so arranged for Wrottesley, and Plate VI. for Liverpool.

Beginning with the N.N.E. (Plate IV.), and proceeding through the easterly points to S.E., the curves present no very striking features; in some months they approach that of temperature, as the N.E. in April, the E.N.E. in February, May, and October, also the E. in February, May, June, October, and November. The prevalence of winds having an easterly or northeasterly bearing during the spring and early summer is also seen, but their particular periods and amount are more perfectly shown in the diagrams of "Diurnal Variations" than in those which are prepared for exhibiting the horary variations.

The S., S.S.W. and S.W. currents, or anti-trade-winds, are the next in order, and exhibit some remarkable features. Independently of the great and sudden increase in the amount of these, especially of the south, when compared with any of those from the east, it will be observed that they exhibit a striking peculiarity in the horary curves; for while the greatest amount of air passes from the south *before* noon, diminishing rapidly for several hours *after* noon, with the S.W. the reverse of this takes place, the greatest quantity passing after noon and the least *before*—the intermediate wind, namely, the S.S.W. showing the most in the middle of the day. It will be observed that the winds on either side of these three, namely, the S.S.E. and W.S.W., partake of the same peculiarity, but in a less degree, the former having its maximum in the morning, and the latter in the afternoon.

The west and north-westerly currents present variations that show the greatest difference between the amount of air that passes by day when compared with the night, and correspond most nearly with the curve of temperature. The N.N.W. winds in the summer months, and especially in June and July, show the greatest extreme, while the winter months indicate the least difference between the day and night.

HORARY VARIATIONS.

TABLE I.—SOUTH.

WROTESLEY.

| | 1 A.M. | | 2 A.M. | | 3 A.M. | | 4 A.M. | | 5 A.M. | | 6 A.M. | | 7 A.M. | | 8 A.M. | | 9 A.M. | | 10 A.M. | | 11 A.M. | | 12 A.M. | |
|------------|--------|------|--------|------|--------|------|--------|------|--------|------|--------|------|--------|------|--------|------|--------|------|---------|------|---------|------|---------|------|
| | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. |
| Dec. 1857. | 125 | 11 | 155 | 12 | 116 | 9 | 87 | 8 | 95 | 9 | 116 | 10 | 125 | 8 | 131 | 11 | 140 | 11 | 156 | 11 | 154 | 12 | 151 | 10 |
| " 1858. | 105 | 8 | 81 | 6 | 93 | 9 | 66 | 6 | 118 | 10 | 127 | 11 | 100 | 8 | 126 | 11 | 102 | 8 | 104 | 8 | 82 | 6 | 65 | 6 |
| " 1859. | 59 | 6 | 60 | 5 | 78 | 7 | 61 | 6 | 70 | 6 | 60 | 5 | 102 | 7 | 62 | 7 | 115 | 9 | 118 | 10 | 133 | 11 | 118 | 8 |
| " 1860. | 30 | 4 | 58 | 6 | 53 | 5 | 52 | 5 | 37 | 3 | 38 | 4 | 38 | 4 | 45 | 4 | 35 | 3 | 39 | 3 | 4 | 1 | 2 | 1 |
| " 1861. | 114 | 8 | 132 | 8 | 84 | 6 | 58 | 4 | 91 | 6 | 73 | 7 | 126 | 10 | 59 | 5 | 76 | 6 | 51 | 5 | 101 | 7 | 90 | 7 |
| " 1862. | 96 | 7 | 106 | 7 | 79 | 5 | 108 | 8 | 90 | 8 | 79 | 6 | 86 | 6 | 46 | 4 | 89 | 6 | 103 | 7 | 93 | 7 | 91 | 6 |
| " 1863. | 12 | 1 | 13 | 1 | 15 | 1 | ... | ... | ... | ... | 21 | 1 | ... | ... | ... | ... | ... | ... | 10 | 1 | 10 | 1 | 10 | 1 |
| " 1864. | 68 | 6 | 71 | 6 | 90 | 7 | 93 | 9 | 79 | 7 | 90 | 9 | 104 | 8 | 74 | 6 | 81 | 7 | 110 | 9 | 101 | 8 | 98 | 8 |
| Mean..... | 76.1 | 6.4 | 84.5 | 6.4 | 76.0 | 6.1 | 65.6 | 5.8 | 72.5 | 6.1 | 75.5 | 6.6 | 85.1 | 6.4 | 67.9 | 6.0 | 79.8 | 6.3 | 86.4 | 6.8 | 84.8 | 6.9 | 78.1 | 5.9 |

| | 13 P.M. | | 14 P.M. | | 15 P.M. | | 16 P.M. | | 17 P.M. | | 18 P.M. | | 19 P.M. | | 20 P.M. | | 21 P.M. | | 22 P.M. | | 23 P.M. | | 24 P.M. | |
|------------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|
| | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. |
| Dec. 1857. | 105 | 7 | 97 | 8 | 137 | 10 | 124 | 10 | 135 | 12 | 134 | 12 | 122 | 11 | 143 | 12 | 138 | 13 | 142 | 13 | 173 | 14 | 182 | 15 |
| " 1858. | 100 | 8 | 81 | 8 | 80 | 7 | 18 | 2 | 25 | 4 | 67 | 5 | 50 | 5 | 50 | 4 | 37 | 3 | 76 | 7 | 113 | 9 | 111 | 10 |
| " 1859. | 108 | 7 | 87 | 7 | 77 | 9 | 72 | 6 | 52 | 4 | 47 | 4 | 47 | 4 | 41 | 3 | 27 | 3 | 34 | 3 | 59 | 6 | 51 | 5 |
| " 1860. | ... | ... | 11 | 1 | ... | ... | 22 | 2 | 18 | 2 | ... | ... | 9 | 1 | 8 | 1 | 10 | 1 | 31 | 3 | 15 | 3 | 35 | 5 |
| " 1861. | 89 | 6 | 94 | 7 | 89 | 7 | 88 | 6 | 123 | 7 | 125 | 7 | 120 | 8 | 94 | 6 | 57 | 3 | 77 | 6 | 131 | 9 | 100 | 7 |
| " 1862. | 81 | 5 | 75 | 5 | 53 | 4 | 76 | 5 | 79 | 6 | 64 | 5 | 57 | 5 | 46 | 4 | 80 | 7 | 106 | 9 | 101 | 8 | 97 | 7 |
| " 1863. | 23 | 2 | 32 | 2 | 34 | 2 | 14 | 1 | ... | ... | 12 | 1 | ... | ... | ... | ... | 8 | 1 | 16 | 2 | 16 | 2 | 11 | 1 |
| " 1864. | 88 | 8 | 70 | 7 | 51 | 5 | 62 | 6 | 63 | 5 | 76 | 6 | 77 | 7 | 76 | 6 | 78 | 6 | 66 | 5 | 83 | 6 | 75 | 6 |
| Mean..... | 74.3 | 5.4 | 68.4 | 5.5 | 65.1 | 5.5 | 59.5 | 4.8 | 61.9 | 5.0 | 65.6 | 5.0 | 60.3 | 5.1 | 57.3 | 4.5 | 54.4 | 4.6 | 68.5 | 6.0 | 86.4 | 7.1 | 82.8 | 7.0 |

On reference to the diagrams of the Liverpool horary variations (Plate VI.), it will be observed that the same general character of curves exists as at Wrottesley, though the amount of air indicated as passing from the various points differs considerably. The amount of east and north-easterly winds recorded is, however, much less, owing to the observatory being somewhat sheltered on that side by the town. The peculiar horary variations which at Wrottesley are exhibited in the S. and S.W. winds, extend at Liverpool from the S.E. to the W.S.W., the former showing the greatest amount in the morning, the latter in the afternoon. The extension of these variations over so many points of the compass forms one of the most striking differences between the observations taken at this station and those at Wrottesley. No doubt the course and valley of the river Mersey lying in a S.E. direction, also the town of Liverpool situated to the N.W., would have a considerable influence in deflecting these south and south-westerly currents, and in giving them a more easterly bearing; though probably there are other causes in action yet to be discovered.

The west and north-westerly currents show the same peculiarities as to the difference between the amount of motion in the day and night as at Wrottesley, and at this station exceed that of any other wind.

The integrating registers for Birmingham having been taken for only three years and a half, have not been engraved; they present much the same features in their horary variations as the observations taken at Wrottesley, the only difference worth mentioning being in the great S.W. or anti-trade-current, which has a rather more westerly bearing at Birmingham than at Wrottesley.

The curves that have been obtained by projecting these integrating records of horary variations, especially those of the south and south-westerly winds, differ much from those of force or velocity as given by me in former papers to this Association, when it was shown that the latter nearly coincide with the curves of temperature, the greatest force occurring at or shortly after noon; but by subjecting the present observations to the test of velocity by dividing the number of miles of air that pass during each hour of the day throughout the year, by the number of hours occupied in passing (see Table II.) it will be found that the law as to the period of greatest force or velocity is still correct, notwithstanding that some of the curves show a larger amount in other parts of the day. These curves are therefore interesting and important, as showing that the different currents have forces acting on them producing horary variations, besides those of acceleration from increase of temperature. In the last row of diagrams, Plates V. and VI., curves are projected on an enlarged scale, showing the horary variations in the velocity of the air at Wrottesley and Liverpool.

The next series of observations have reference to the amount and direction of the various winds throughout the year. In tabulating these, it was necessary that each day should be recorded separately, for by throwing together an arbitrary term of days, as a month or even a week, many important facts would be lost. The records have therefore been tabulated so as to give the direction, duration, and amount of horizontal motion of the air for every day in the year for seven years, referred to sixteen points of the compass. Commencing with the 1st of January in each year, the number of hours that each current has lasted, and its amount of horizontal motion during the day, are obtained from the diaries in which the indications registered by the instruments are recorded, and this is repeated in rotation for every day during seven

years, thus sorting, as it were, all the winds. The mean amount of these is then taken for each day, as represented in Table III., showing the daily amount and duration of south wind during the month of January.

From these Tables diagrams are drawn (see Plates VII. & VIII.), representing to a scale the comparative number of miles of air that passed from each point of the compass for every day in the year, taken from a mean of seven years, the length of the line being in proportion to the length of the current from each point on each particular day. An approximate meteorological division of the year is thus obtained, having reference to the currents that pass each station.

When examining these diagrams it is important not to be misled by the extent of a current that was due to one or two years being mistaken for the type of a period of years. A space is therefore allotted under each day, which is divided into seven parts, representing the seven years. One of these divisions is then marked to indicate the year in which each wind occurred, the size of the mark having reference to its duration on its particular year. By these means the prevalence or otherwise of any wind at any period of the year is at once rendered conspicuous.

The diagrams explain this mode of illustration. Thus at Wrottesley (Plate VII.*), commencing with the north-easterly and easterly winds, a remarkable cessation is observable towards the end of January and beginning of February, again at the end of June, also at the beginning of August and September, and in the early part of December, while the amount towards the end of February, and the prevalence in April, and more particularly in May, often extending to the early part of June, is very clearly shown.

The S. to the W.S.W. winds have their maximum in January, increasing greatly towards the end of the month. They also prevail in the early part of April, during the latter half of July, and through the month of August, and more than any other current in September.

The winds from the W. and N.W. prevail in March, towards the end of May and in June, especially in the latter half of that month. During the last four months of the year currents from these points are exceptional.

On reference to the diagram representing the diurnal variations of the wind at Liverpool (Plate VIII.), it will be observed that there is the same cessation of the easterly and north-easterly winds at the end of January and beginning of February as at Wrottesley, also at the end of June, &c. The times of prevalence also occur about the same periods. The S.E. and S.S.E. winds, however, correspond to the periods of the S. and S.S.W. at Wrottesley, and the S.S.W. and S.W. at Birmingham.

The W. and W.N.W. winds prevail with considerable regularity in March, also at the end of April and beginning of May, again at the end of May, and particularly at the end of June, extending into the early part of July, and at the end of August and first portion of September. The diagrams show better than any written description the features of each current.

The last row of diagrams in each of the Plates VII. & VIII. represents the mean amount of horizontal motion of the air, without reference to direction, for every day in the year—projected on the same scale as the separate winds. From these it will be observed that a considerable amount of mo-

* In Plate VII.*a*, the portions of Plate VII. which exhibit the duration of each wind on every day throughout the seven years, are brought together in such close juxtaposition, as to give a comprehensive view of the periods of prevalence of each wind during that term of years at Wrottesley. The points from N.N.E. to S.S.E. are repeated.

DIURNAL VARIATIONS.
TABLE III.—SOUTH.

WROTTESELEY.

| | Jan. 1. | | Jan. 2. | | Jan. 3. | | Jan. 4. | | Jan. 5. | | Jan. 6. | | Jan. 7. | | Jan. 8. | | Jan. 9. | | Jan. 10. | | Jan. 11. | |
|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|----------|------|----------|------|
| | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. |
| 1858 | 275 | 24 | 201 | 20 | 128 | 10 | ... | ... | ... | ... | 111 | 12 | 387 | 22 | 189 | 13 | 30 | 2 | 204 | 12 | 49 | 2 |
| 1859 | 53 | 5 | ... | ... | 6 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 34 | 5 | ... | ... | ... | ... |
| 1860 | 127 | 6 | 19 | 2 | 162 | 10 | 36 | 3 | 102 | 8 | ... | ... | ... | ... | 108 | 8 | 151 | 18 | ... | ... | ... | ... |
| 1861 | ... | ... | ... | ... | ... | ... | 7 | 2 | ... | ... | ... | ... | ... | ... | 232 | 20 | 235 | 21 | 131 | 16 | 80 | 8 |
| 1862 | ... | ... | 6 | 1 | ... | ... | ... | ... | ... | ... | 36 | 6 | 186 | 14 | 157 | 9 | 58 | 4 | 25 | 2 | 157 | 9 |
| 1863 | 18 | 1 | 82 | 5 | 98 | 10 | 142 | 10 | 96 | 12 | 15 | 2 | 96 | 9 | 11 | 2 | ... | ... | ... | ... | ... | ... |
| 1864 | ... | ... | 5 | 1 | ... | ... | ... | ... | ... | ... | 13 | 6 | ... | ... | 5 | 1 | ... | ... | 48 | 6 | 73 | 7 |
| Mean | 67.6 | 5.1 | 44.7 | 4.1 | 56.3 | 4.4 | 26.4 | 2.1 | 28.3 | 2.9 | 25.0 | 3.7 | 95.6 | 6.4 | 100.3 | 7.6 | 72.6 | 7.1 | 58.3 | 5.1 | 51.3 | 3.7 |

| | Jan. 12. | | Jan. 13. | | Jan. 14. | | Jan. 15. | | Jan. 16. | | Jan. 17. | | Jan. 18. | | Jan. 19. | | Jan. 20. | | Jan. 21. | | Jan. 22. | |
|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|
| | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. |
| 1858 | 72 | 6 | ... | ... | ... | ... | ... | ... | ... | ... | 3 | 1 | 11 | 1 | ... | ... | ... | ... | ... | ... | ... | ... |
| 1859 | ... | ... | ... | ... | 22 | 6 | 245 | 20 | 431 | 22 | 167 | 10 | ... | ... | 9 | 1 | 383 | 21 | 557 | 24 | 119 | 9 |
| 1860 | ... | ... | ... | ... | 72 | 5 | 321 | 15 | 67 | 5 | 68 | 9 | ... | ... | 86 | 8 | 168 | 10 | 131 | 7 | ... | ... |
| 1861 | 166 | 12 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 167 | 17 | 37 | 4 | ... | ... | ... | ... |
| 1862 | 62 | 6 | 66 | 9 | ... | ... | ... | ... | 35 | 3 | ... | ... | 79 | 12 | ... | ... | ... | ... | ... | ... | ... | ... |
| 1863 | 74 | 8 | 53 | 8 | ... | ... | ... | ... | ... | ... | ... | ... | 88 | 6 | ... | ... | ... | ... | ... | ... | 224 | 14 |
| 1864 | 183 | 12 | 20 | 3 | ... | ... | ... | ... | 10 | 1 | 40 | 3 | ... | ... | ... | ... | ... | ... | 37 | 3 | 39 | 3 |
| Mean | 79.6 | 6.3 | 19.9 | 2.9 | 13.4 | 1.6 | 83.4 | 5.4 | 77.6 | 4.4 | 42.3 | 4.1 | 35.7 | 4.4 | 64.4 | 5.6 | 117.7 | 7.6 | 120.7 | 5.9 | 56.6 | 3.9 |

| | Jan. 23. | | Jan. 24. | | Jan. 25. | | Jan. 26. | | Jan. 27. | | Jan. 28. | | Jan. 29. | | Jan. 30. | | Jan. 31. | |
|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|
| | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. | miles. | hrs. |
| 1858 | 7 | 1 | 85 | 11 | 191 | 11 | ... | ... | 9 | 1 | 190 | 16 | 65 | 6 | ... | ... | ... | ... |
| 1859 | 287 | 12 | ... | ... | ... | ... | ... | ... | ... | ... | 11 | 1 | 307 | 16 | ... | ... | ... | ... |
| 1860 | 121 | 6 | 43 | 5 | ... | ... | 31 | 4 | 24 | 2 | 111 | 8 | 5 | 1 | 39 | 3 | 53 | 4 |
| 1861 | 192 | 21 | 330 | 21 | 105 | 5 | 58 | 4 | 63 | 7 | 183 | 18 | 98 | 10 | 85 | 8 | ... | ... |
| 1862 | 178 | 12 | 223 | 11 | ... | ... | 107 | 17 | 178 | 10 | 83 | 6 | 88 | 7 | 282 | 21 | 352 | 21 |
| 1863 | 69 | 4 | 86 | 5 | ... | ... | 60 | 3 | ... | ... | 151 | 11 | ... | ... | 42 | 5 | ... | ... |
| 1864 | ... | ... | ... | ... | 16 | 2 | 112 | 10 | 40 | 3 | ... | ... | 84 | 10 | 35 | 2 | ... | ... |
| Mean | 122.0 | 8.0 | 109.6 | 7.6 | 44.6 | 2.6 | 52.6 | 5.4 | 44.9 | 3.3 | 104.1 | 8.6 | 92.4 | 7.1 | 101.4 | 7.6 | 93.6 | 6.0 |

tion takes place throughout the year, and that no period can be regarded as calm. The early part of January is, however, much calmer than might be expected, while the latter portion of that month and beginning of February are just the reverse, as is also March. The great increase observable in the portion of the diagram that shows the amount of motion of the air that passes Liverpool at the end of June and beginning of July, is due to the very strong W., W.N.W., and north-westerly currents at that period of the year. At Wrottesley the same currents exist, and at the same period, but their violence is so much diminished as not to disturb the general averages.

These observations seem to indicate, both from the diagrams of each day as well as from those exhibiting the horary variations, that there are three principal currents or groups of winds that may be classed together. First the north-easterly, prevailing mostly in the spring, and also appearing in the autumn. Whether they may be regarded as a temporary extension of the trade-winds will require further observations to determine. They possess some of the characteristics of that wind.

The next group is the great south and south-westerly current, or anti-trade-wind, the peculiar horary variations of which and periods of greatest motion have already been referred to.

The currents from the N.W., including those from W. to N.N.W., form the last group.

Although the north-west and south-west groups are in many respects distinct from one another, yet they often blend so much that it is not possible to draw a definite line between them.

Further observations on a more extended scale are required to define with accuracy the periods of prevalence or otherwise of the various currents, and to determine many interesting points regarding their course and action, which can now be only dimly shadowed forth. It is, however, hoped that what has here been done will aid in showing the importance of keeping a constant record of the movements of the air over as large an area of the earth's surface as can with convenience be arranged. The geologist, whose researches also extend over the whole earth, finds in the great globe itself a vast registering instrument, where the changes that he is studying have been permanently written, enabling him at his leisure to examine its records, and refer to periods so immeasurably distant that he may, by reversing his train of thought, have glimpses of eternity. The meteorologist, on the contrary, finds himself lost by reason of the ephemeral nature of the forces and conditions which he has to deal with; he requires all the artificial appliances that can help him, to take note of and record the various changes that occur; but of all the conditions, there are none more important than those of the great currents of the atmosphere. A knowledge of the quarter from which the air arrives at given points on the earth's surface, and the duration of the current, will be a key to its various conditions of temperature, humidity, weight, and all the other features it may possess; while to trace it onward, over a large area, will materially aid in unravelling the secrets of the producing causes, and the laws that determine its course.

Second Report on the Physiological Action of certain of the Amyl Compounds. By BENJAMIN W. RICHARDSON, M.A., M.D., F.R.C.P.

AT the last Meeting of the Association, I read before the Physiological Section a "Report on the Physiological Action of Nitrite of Amyl." On that occasion the members were good enough to express a wish that I should continue the inquiry. The present Report is the result.

In accordance with the desire of the Committee, I have in this Report carried out a more general enquiry. Instead of confining myself to one special body in the amyl series, I have taken several of them, viz. amylene or valerene as one of the simplest of the type, amylic alcohol, acetate of amyl, and iodide of amyl.

I hope, from the researches I have made, to leave in the hands of the Association a fair history of the physiological value of all these compounds.

Before proceeding further, permit me to invite the attention of the Section to a very brief summary of the facts brought forward at our last Meeting, in 1864, respecting the nitrite of amyl. I showed then that nitrite of amyl was—

1. The most powerful excitant of vascular action known.
2. That in animals whose bodies admit of its spontaneous evaporation, the nitrite suspends animation; and that in animals of higher organization it induces a condition resembling cataleptic insensibility.
3. That it is not an anæsthetic.
4. That the effects produced by it are developed on the motive powers of the organism, which it first vehemently excites, and then paralyzes.
5. That it arrests the process of oxidation.

I shall not trouble the Section with further observations in detail on this compound, inasmuch as the report upon it, as a whole, is published in the Transactions of the Association. I pass therefore at once to the other compounds of the amyl series.

AMYLENE.

The substance called amylene was first separated by Balard, of Paris, twenty-one years ago. It attracted but little attention until 1856, when Dr. Snow having read of it, and learned theoretically its composition and physical characteristics, came to the conclusion, on theoretical grounds only, that it was possessed of anæsthetic properties. In process of time he obtained some of the fluid; he found that his theory proved correct in practice, and he was so satisfied with the action of the substance, that he employed it as an anæsthetic in 238 cases. M. Giraldis, of Paris, also employed it in seventy-nine cases. I used it myself in connexion with Snow in three cases, and many other physicians and surgeons used it also. For a time, indeed, it seemed that amylene would in the end take the place of chloroform, but the promised success was marred by the occurrence of two fatal cases, from its inhalation, in the hands of Snow himself.

Since that period, (July 30, 1857, date of the second fatal case,) amylene has fallen into entire disuse. Snow during the last year of his useful life returned to chloroform, and I have occasion to know, from my intimate friendship with him, that the occurrence of the fatal accidents caused him as much anxiety as surprise. It has been suggested since Snow's death that the specimen of amylene which he used was not pure, but was in fact a compound of various substances. This may be true, but it is certain that he had used the same specimen successfully in other cases, and I have experi-

mented on animals with a little that remained from the same store, without producing any dangerous symptoms.

I introduce amylene to notice in this place, because it not only links itself naturally with the series, but is, in fact, a proper body of the series from which to date observations as to variation of action.

Amylene is made by acting on pure fusel oil or amylic alcohol with chloride of zinc; it has also been obtained, together with hydruret of amyl, by the action of zinc on iodide of amyl. In the distillation of the amylene other products are almost certain to pass over, and I think I am right in saying that the substance has never been obtained actually pure for physiological purposes. It ought, when quite pure, to be neutral to potassium, and to preserve that element from oxidation; but, as far as I am aware, this degree of purity has not been secured. The liquid has an oily character, and an odour compared by most persons to raw whiskey. It boils at the temperature of the blood, 98° Fahr.; it is soluble in alcohol and ether to any degree, it is soluble in water to the extent only of one part in 9319, and the specific gravity of its vapour, according to Snow, is as low as 2.45. As a fluid it is nearly colourless. It is composed of two elements, $C_{10}H_{10}$.

Antiseptic Properties.—Like the nitrite of amyl, amylene is antiseptic; if dead tissue be placed in the pure vapour of amylene securely it remains unchanged, but the great difficulty consists in retaining the vapour in the vessel. If 60 grains of amylene be placed in a jar having a cubic capacity of 80 inches, the organic substance to be preserved being previously put into the jar, sufficient amylene may be diffused by the warmth of the hand to enable the specimen to be kept in preservation. Animal tissues in amylene-vapour do not gelatinize as in ammonia; they become soft, evidently from the action of water retained in them, but not offensive. Decomposed animal tissue placed in vapour of amylene does not become less offensive, although the process of putrefaction is for a time arrested.

Amylene preserves blood from putrefaction so long as it is present in the mass. During the past weeks of extreme heat I have retained blood unchanged in my laboratory by simply treating it, from time to time, with sufficient amylene to render the odour of the substance detectable. After it has been for a time in contact with blood in a closed bottle, the odour evolved resembles rosemary so closely as not to be distinguished from it.

Effects on Flowers.—Amylene prevents the decomposition of fresh flowers, but it is not applicable as a preservative, owing to the change it produces in colour. The leaves pass from green to a dirty brown, the yellow colour grows slightly dingy, and the red fades. The colour least influenced is yellow.

Physiological Effects on Living Organisms.—Amylene does not in any degree irritate either the skin or mucous membrane; it acts feebly when exhibited by the mouth or by injection under the skin. It is by inhalation only that we can bring out its actual properties.

I have administered amylene in vapour to dogs, cats, guineapigs, and men. The symptoms presented in all are in the main the same. There is not the terrific excitement of the circulation which is seen when the nitrite of amyl is used, but there is some excitement, and there is quick inebriation.

This is followed by powerlessness of the limbs, and sudden collapse and coma, with total insensibility to pain, but not always, and indeed rarely, with an equivalent loss of consciousness. In one case I saw a person who was under amylene, and entirely senseless to a severe surgical operation,

talking with considerable correctness on the topics of the day, seizing objects with precision, and showing scarcely a perceptible gradation during recovery from mental inebriation to perfect and sober consciousness. In a psychological point of view this fact is doubly interesting, for the expression of consciousness is but a semblance. The person on recovery does not remember the period when, to the bystander, he seemed as wide awake as one unaffected. To test this phenomenon I myself inhaled amylene alone, and, before inhaling it, made up my mind that I would test for sensibility by pinching my hand. I inhaled, sitting in an arm-chair, 10 grains of amylene from a jar holding 100 cubic inches of air; the air was thus charged with rather more than 13 per cent. of amylene-vapour; this quantity is small, except it be inhaled backwards and forwards in the manner I then followed, when the action is quickly decisive. Soon after inhaling I forgot myself altogether, but four minutes from the time I took up the jar I was quite conscious again, waking as if with a start. Ah! I thought, this experiment will not do; the amylene acts so quickly that there is no interval during which a man may test his own sensibility; but turning now to my wrist, I found I was wrong in this suspicion, for there were deep marks of pinches in several places; and further, the bottle containing the amylene-vapour had been replaced on the table with the stopper firmly adjusted, as I had intended. Thus I had, in fact, been performing acts of consciousness preconceived and carefully carried out without remembering any single fact connected with the process.

I have seen a phenomenon nearly similar under chloroform, but never so marked as under amylene. Snow had an experience of the same in kind. During a severe operation on a child under the influence of amylene, the child was playing with a ball, throwing it into the air, catching it with precision, and talking and laughing the while.

I presume that there is not one hearer present who, quite irrespectively of the special subject of this report, will not, on contemplating the phenomenon just cited, be struck with the facts adduced. It is clear that the human mind, through its manifestations, may exhibit a mere objective consciousness apart from the ordinary subjective consciousness of daily life. It may exhibit a consciousness of which it is itself unconscious, and this under the mere influence of a volatile liquid obtained from common potato-starch, and which mixes so indifferently with blood at 96° Fahr., that one part only will combine with 10,550 parts of blood.

Have we any analogous phenomena apart from experiment, and spontaneous or natural like this? You will all anticipate me when I say yes, there is the very counterpart in somnambulism. The somnambulist is in precisely the same state as the experimentalist under this amyl-compound: he pursues acts of consciousness of which he is not self-conscious; he presents to us, *i. e.*, mere objective consciousness. Have we not here a key to the hitherto mystery of sleep-walking and acting? I will not say it is certain, but the evidence is as clear as inferential evidence can ever be, that persons who are subjects of somnambulist movements do, through some abnormal process of digestion or respiration of the starchy elements of food, produce in their own organisms by their own organic chemistry, an agent which, like amylene, destroys remembrance, and perhaps judgment and reason, but which leaves the brain still able to act and to direct the limbs to do things which they could not do better in the most wakeful hour.

One might linger long on this subject, but I must leave it after noticing yet one other peculiarity of what may be called amylene dreaming. It is this, that during the period of insensibility the mind is capable of carrying on

certain proceedings upon which it was predetermined. We have a similar phenomenon to this in our daily range of experience, in the fact that we can under pressure go to sleep determining that we will wake at a certain time, and do so almost to the minute. In both these cases it seems as though the dark sleep were pierced by one pervading conscious gleam of light which obeys the orders it has received, and watching the slumbering spirits around it, calls them forth into activity at the proper time, and then itself dies away.

The insensibility produced by amylene is very complete but exceedingly transient; recovery after the vapour is withdrawn is sudden, and it is therefore necessary to keep up the effect by constant inhalation of large quantities of the vapour. Between the period of full sensibility and complete insensibility there are three well-marked stages. The first is one of mild excitement, during which the face becomes red and injected; then a period of staggering inebriation; and thirdly, a period of collapse and insensibility. Snow added a fourth stage of entire muscular relaxation, but I have myself not been able to follow it. During narcotism from this agent there is no convulsion, but not unfrequently there is a peculiar tremor of the muscles very general, but, if I may use the term, minute. Carried to an extreme, the vapour kills animals. The only structural peculiarity found after death, is engorgement of the right side of the heart. The lungs are healthy, and the blood is unchanged in its general physical properties. I would dwell on this last fact with emphasis in order to correct an error made by the reporter on amylene to the Academy of Medicine of Paris, to the effect that amylene removed the red colour from arterial blood, whereas chloroform does not. This is a mistake, founded obviously on an inference derived from imperfect observation. When amylene is added in quantity to arterial blood drawn from the body, it does unquestionably produce darkness of colour; but in the living animal, during its exhibition by inhalation, no such event occurs; for I have taken the blood from artery and vein, and have compared the specimens. The colour of both bloods is normal, the period of coagulation is natural, and the corpuscles are unchanged.

Owing to the fact that amylene is feebly soluble in water, and therefore feebly soluble in serum of blood, a very large percentage of it requires to be inhaled before any effect is produced. Snow estimated that the air must be charged with 40 per cent. in order to produce entire insensibility, and in fact he under-estimated the quantity by working on water at a temperature of 56° instead of 96° Fahr. I find that, instead of 40, 50 per cent. of the vapour actually is required. But as the blood at its ordinary temperature can only absorb $\frac{1}{10000}$ th part of the vapour of amylene, it cannot, even in an adult man, receive at any time more than from $4\frac{1}{2}$ to 5 grains. It is clear, too, from the rapidity with which recovery takes place, that the fluids of the tissues receive but feeble impregnation.

In order to institute a physiological comparison, I tried the effect of the analogue of amylene olefiant gas. Olefiant gas is the hydruret of acetylene, but, like amylene, it is a pure hydrocarbon; its composition is different only in one respect, viz. that it is composed of four equivalents of carbon and four of hydrogen. As I had anticipated, the action was nearly the same; to produce perfect insensibility, 50 per cent. of the gas was required in inhalation. The effects also were transient.

The effect of amylene on the muscular tissue was studied in various ways. As will already have been gathered, it reduces the muscular power, but the effect is not abiding. In fact amylene approaches the class of

negative narcotics, and enters into no chemical combination with the tissues. This fact led Dr. Snow to say that in action it almost resembled nitrogen. I should myself rather compare it to carbonic oxide; only that carbonic oxide produces convulsive movements and vomiting, which amylene rarely does.

When an animal has died from amylene, the peculiar odour of the substance may be detected in the tissues for many days. This circumstance may seem at first sight to be opposed to the statements already made respecting the feeble absorption of the vapour by the blood. However, there is no contradiction; the phenomenon is due to the circumstance that amylene possesses the power of charging water with its own odour and taste when in extreme division. This fact was observed by Snow with his usual precision. "Amylene," he says, "requires 9319 parts of water for its solution;" and, he adds, "the water which has dissolved this small quantity of amylene tastes as distinctly of it as amylene itself." I notice this peculiarity, as it might happen some day to be of service in medico-legal investigations.

AMYLIC ALCOHOL.

Amylic alcohol, the hydrated oxide of amyl, is obtained in the fermentation of potato-starch or starch of grain. It is an almost colourless fluid, and boils at 270° ; its density is 0.818. Its smell is sweet, nauseous, and heavy. In composition it differs from amylene in that it contains oxygen; its chemical composition is $C_{10}H_{12}O_2$. Its solubility in water is about the same as amylene.

In action it resembles amylene in being antiseptic, and in changing the colour of flowers and plants. It acts on the body, whether administered by the mouth or by inhalation, but it is most effective when inhaled in minute subdivision from an atomizer.

Administered by inhalation in small quantities, it produces in the first instance signs of irritation of the nostril and then of drowsiness, but there is no anæsthesia; if the inhalation be continued, and the quantity increased, the symptoms of coma or sleep are more fully developed, but without any insensibility, and with almost immediate recovery on the animal being removed. Pushed further still, the animal sinks on its side and loses the use of the limbs. At last the coma becomes very profound, and it may be intensified up to the point of insensibility. At this stage of the process, and sometimes a little before it, a peculiar symptom is developed, viz. a universal tremor, accompanied with a very deep inspiration. There is no spasm, no pain, no rigidity, but in medical language rigors of an intense kind. These rigors are soon established in regular rhythm, and by maintaining the experiment cautiously, they may be kept up for several hours. I have seen them for one hour at the rate of sixteen in a minute as regularly as possible, and by reduction of the agent have lowered them to twelve, eight, and four per minute. All through the breathing is tranquil and the action of the heart good. The rigor occurs spontaneously in this manner, but it can be excited at any moment by touching the animal or blowing upon it, or even by a sharp noise, such as the snap of the finger. When the animal is reduced to entire insensibility, if it be laid in the open air, it begins to recover its sensibility at once, but the power to move is suspended for two or three hours, and the rigors also continue, but with decreasing force and frequency. Ultimately the animal recovers thoroughly, and is always very eager for food. When these urgent and, as they would seem, extreme symptoms are carried

to their full extent, even an experienced observer would think that recovery were impossible; but in truth the animal cannot be killed by any fair play with this vapour. In order actually to kill, it is necessary to complicate the experiment by actual reduction of air, or by closing the chamber and retaining the carbonic acid of the breath. Amylic alcohol produces a crenate and slightly shrunken condition of the blood-corpuscles, and the red blood is slightly darkened by it, but no change is produced in the property of coagulation. The odour of the substance remains for many hours in the tissues. The oxide has little action on the skin.

ACETATE OF AMYL.

The acetate of amyl is made by distilling together 1 part of potato oil, 2 of acetate of potassa, and 1 of concentrated sulphuric acid. The distilled fluid is washed with alkali, and distilled from chloride of calcium. It boils at 272° . Its composition is $C_4H_9O_2$.

Acetate of oxide of amyl is a compound of oxide of amyl with acetic acid. It is a clear fragrant fluid, and is sold for flavouring purposes under the name of essence of pears. It acts like the other preparations in preserving organic substances.

Physiologically the effects of the acetate of amyl may be induced feebly by subcutaneous injection, or by administration by the mouth, but best by inhalation from the atomizer. It is very pleasant to inhale, and produces scarcely any irritation. When inhaled by an animal, it produces the very same symptoms as amylic alcohol; indeed these are so closely alike, that I could not by mere observation of the symptoms tell which agent was being employed. It is quite possible to induce perfect insensibility to pain by this agent. The rigors, so remarkable as regards their regularity of occurrence, are presented in marked degree; a touch or noise calls them into action, and the paralysis of the voluntary muscular system is complete; but by itself the acetate does not destroy, and I have held an animal under its influence for ten hours with perfect recovery afterwards.

I have inhaled the vapour myself in proportions varying from fifteen to twenty-five per cent. without any unpleasant symptom. It slightly quickens the action of the heart, and it produces a little irritation of the throat, such as follows the inhalation of vapour of vinegar, but, on the whole, the effect is pleasant. After a short time there is a gentle sensation of drowsiness, but no loss of sensation nor of consciousness, no faintness, no nausea, but a slight tremulousness of the muscles, the same unquestionably as the tremor which is seen in the more determinate manner in the lower animals.

The acetate of amyl does not interfere with the process of coagulation of the blood, but it renders the blood darker in colour, and the corpuscles are made irregular and crenate. The odour of it does not remain long in the tissues. The acetate exerts a feeble action upon the skin, causing some vascularity and soreness when long applied.

IODIDE OF AMYL.

The iodide is made by distilling together 15 parts of potato oil, 1 of phosphorus, and 8 of iodine. It volatilizes, without being decomposed, at 294° .

The iodide of amyl is a compound of amyl with iodine. Its composition is $C_{10}H_{21}I$.

It is a slightly pinkish liquid, the odour is less agreeable than that of the acetate of amyl, but is more pleasant than that of amylic alcohol. It rapidly changes the colour of flowers and plants, and although it is an antiseptic

when brought into contact with dead organic material, it is much less active in this respect than any of the compounds which have up to this time been before us.

The physiological action of the iodide of amyl is well illustrated when the substance is administered with the atomizer, but it may be administered by direct inhalation. The symptoms induced are peculiar, being a mixture of those brought out by the nitrite of amyl, the hydrated oxide and the acetate. In the first stage of inhalation there is a profuse flow of tears and increase of saliva, followed by rapid breathing and vehement action of the heart. In the second stage there is prostration of the muscular system with commencing rigors; in the third stage there is entire prostration, and precisely as with the oxide and acetate, there are regular series of general tremulous movements which can be excited at any moment by touching or by a sharp noise. During the tremor the limbs are agitated in movements which are so rapid that they cannot be counted. Pushed to a fourth degree, the breathing becomes paralysed, and the action of the heart intermittent and at last prolonged. But at this last degree, when extinction of life is within a second, there is no insensibility to pain. The merest prick causes expression of consciousness. Removed from the vapour, even when the existence of life is almost doubtful, recovery, if there be the faintest detectable action of the heart, is certain, and not only so, but it is rapid also. In the course of recovery the tremors quickly subside, but a special and curious phenomenon is commonly presented, consisting of a series of revolutions of the body in a circle. At first the animal moves round almost on its own axis; as it regains power, it makes a little circuit, and then a wider one; at length it moves less methodically in jerks, and last of all attains the straight line. It seems at no time to suffer anything, and yet always to be alive to what is passing. It eats food voraciously on recovery. I should add that during the whole process there is copious elimination of water from the lungs, skin, and indeed all the emunctory organs.

If the blood be examined microscopically before, during, and after the inhalation, several changes are observed. The colour of the blood is not darkened, but the fibrine appears to undergo entire solution, while the blood-corpuscles in greater part retain their natural characteristic form. The dissolved condition of the fibrine lasts many hours, and if the skin be pricked the blood flows for an unusual time, but it is bright red in colour. When added to drawn blood, the iodide renders the coagulation loose and feeble, but does not stop the process altogether, possibly because its molecules do not come into such minute contact with the blood as when they are brought into union with the blood in the lungs. The upper surface of blood charged with the iodide becomes oxidized quickly in the air, and exhibits a bright red layer very deep and regular.

The iodide causes little irritability of skin or of mucous membrane. It is not disagreeable to inhale, but it excites secretion of saliva. It also produces vascular redness of the extremities during its inhalation.

In regard to the whole of the amyl-compounds, the properties of which I have investigated, I may state that, while they destroy the voluntary power of the muscles, they seem in no way to destroy the muscular irritability, the *vis insita* of Haller. This is proved by the facts that when the animal lies most prostrate any muscle or any group of muscles can be called into brisk action by the application of the galvanic stimulus, and that when an animal is actually destroyed by them, the muscular irritability remains for many hours after death. When the nitrite is employed as the destructive agent,

the muscular irritability of the heart is retained in some cases for so long a period as eighteen hours; hence I think it follows conclusively that the influence of the poison is exerted mainly on the nervous centres, and that the stimulus to muscular action or the tension of force derived from those centres is simply reduced or withdrawn. I conceive also it is another fair inference to suppose that the compounds exert their influence first on those portions of the nervous organism from which the motor power, as apart from the sensory and conscious, is derived.

Before closing this descriptive section of my report, I would add that, in the experiments to which attention has been drawn, dogs, rabbits, and guinea-pigs were the animals subjected to observation. To make the experiments strictly fair, to forbid any suspicion to the effect that the differences or even the analogies observed were due to peculiarities of the animals, one animal, a strong guineapig, was subjected at intervals of ten days to the extreme action, short of actual death, of the various compounds submitted to examination.

PRACTICAL CONCLUSIONS.

It remains for me now, in a few short paragraphs, to sum up the lessons which are taught by these experiences.

I.—In the first place, something is added to our knowledge of therapeutics or rational principles of remedies. This is hardly perhaps the place to descant on special remedies for the treatment of disease, and I shall forbear on this point; but I may state generally that, according to present knowledge, none of the amyl-compounds can be said to replace either ether or chloroform as anæsthetics: amylene, the best of the series, is known not to be free of danger, and it is less manageable than chloroform without being devoid of any of the objections of chloroform, except the one, that it does not so often produce vomiting. This advantage, though most important, is after all insufficient as a single favourable recommendation.

But there is one direction towards which our minds cannot fail to be directed, and following which we may expect useful results in a therapeutical inquiry,—I refer to the application of these substances as remedies in certain convulsive and spasmodic diseases, in which the symptoms are obviously induced by morbid sensibility or excitability of the motor tracts and centres of the nervous system. When we know that in these agents we possess remedies which produce lessened action of the motor force resident in nervous matter, but which at the same time affect the consciousness in a secondary degree only, and do not affect the muscular irritability at all, we cannot but be impressed with the feeling that they would largely control the nervous excitation in cases where that is dangerously and fatally called forth. I refer more particularly to cases of tetanus or locked jaw. Here I think it would be rational to bring these agents into requisition as remedies, and comparing the agents one by one, and after studying carefully their effects, I should conclude that the iodide of amyl would on the whole be most promising. It has the advantage of being readily administered by inhalation; it produces less muscular excitement than the nitrite, and it is, I believe, chemically a safer preparation; it does not so determinately check oxidation as the rest; it promotes secretion; it is more permanent in its effects than amylene, and it is less persistent than either the acetate or the amylic alcohol. In a case of hopeless tetanus I should have no hesitation in administering iodide of amyl until decided reduction of nervous excitability was indicated,

nor do I doubt the possibility of sustaining such reduction of irritability for several hours.

The iodide of amyl might possibly also be found useful as a means for bringing forth the medicinal virtues of iodine itself in the many cases for which that element is now, under other forms, so usefully employed. It would make, for example, an excellent embrocation for glandular enlargements, and would come in efficiently in other ways, as will occur to every medical practitioner. It is unnecessary, however, to dwell on these matters; having pointed out the physiological bearings of the question and framed the institute, I leave the practice to experience.

II.—In the second place, a lesson is taught by these researches relative to the possible cause, or to some allied cause, of certain diseases as yet most obscure in reference to their causation. I showed last year that the nitrite of amyl produced a condition of system closely allied to the disorder known as catalepsy. On this occasion I have indicated that another of these compounds produces symptoms analogous to those which characterize the disease known as sleep-walking or somnambulism. But it will further occur to the mind of the philosophical pathologist that hysteria and certain sudden and as yet unexplored forms of paralysis of voluntary muscular power, following peculiar dyspeptic derangements, admit of explanation on the hypothesis of a perverted animal chemistry, and the formation in the organism itself of a substance made from the same organic material and approaching in character one of these amyl-compounds. If, as we know is the fact, a peculiar fermentative process of amylaceous material out of the body leads to the production of the base of the amyl series, it is hard to avoid the thought that in the body, where the zymosis of amylaceous matter is a constant process, no similar perversion should occur.

III.—The last lesson suggested by this research relates to the modifications of action exhibited in animals by charging them with the same chemical base but with diverse compounds of the base. A very shrewd and profound question was asked me last year by Dr. Heaton of Leeds, when my report on the nitrite of amyl was read, to this effect:—Is the action of the compound due to the base, or to the compound* as a whole? I was unable then to answer that question properly. Now I can answer it; and I do so by saying, that in the midst of the phenomena observed the base amyl is, if I may use such an expression, the key-note, but variations are introduced as new elements are added. The order of variation is most interesting. We take a simple hydrocarbon, the hydruret of amyl, and we have an almost negative body acting not unlike nitrogen and destroying motor force and consciousness partly but no more. We introduce the element oxygen into the inquiry by using the hydrated oxide of amyl or the acetate, and there is added to the above-named phenomena violent and persistent tremor. We move from this to another compound, and bring iodine into the field, and the phenomena now embrace free elimination of fluid from the body, vascularity of the extreme parts with increased action of the heart and of respiration. We change the combination once more to bring nitrogen and oxygen into operation with the base, and the vascular action is raised beyond what is seen from any other known substance, to be followed by a prostration so profound that the still living animal might for a time pass for dead.

It seems to me, but I put out the thought with the profoundest submission, that in these experimental truths, so simple and yet so striking,

we have presented to our minds a new line of therapeutical inquiry running somewhat parallel with that line of inquiry so prominent amongst our learned and more exact brethren of the Chemical Section, which they follow under the term "the law of substitution." I would ask,—Is there not a physiological law to be worked out similar in character? and might we not by looking into it become more sure and determinate in our knowledge and application of medicinal remedies? What if, after having learned the exact action on the economy of the organic bases, we followed the chemist, and by taking the compounds moulded on those bases, we learned their true physiological values? Surely, if we did this, long though the labour should be, we might in time venture to lay down.

" This osier cage of ours
With baleful weeds and precious juiced flowers"—

and without forgetting the words of that wise friar, whom we of physic still so blindly follow,

" Oh mickle is the powerful grace, that lies
In herbs, plants, stones, and their true qualities,"

might begin to approach to that accuracy of knowledge, the absence of which makes us so weak and the charlatan so presumptuous; the possession of which makes the other physical philosophers so proof against presumption and so proudly certain in their stupendous knowledge.

In conclusion, were I a youth, just entering one of the best professions, I should be glad to devote my first years simply and solely to the branch of therapeutical research which I have here so faintly sketched out. As it is, I can but feel fortunate in that, supported by the fostering care of this Association, I have been enabled to do even so much as turn the first sod in this great and novel field of labour,—I mean the investigation, physiologically, of the organic chemical compounds on a plan that aims at least at a principle in science, however obscurely it may have been propounded. To say I shall be happy to do more, and again to lay what I may have done before this Section, is to say the least I can in return for the kind consideration I have received at your hands.

Report on further Researches in the Lingula-flags of South Wales.

By HENRY HICKS. *With some Notes on the Sections and Fossils,*
by J. W. SALTER, F.G.S., A.L.S.

THE district to which the following Report refers, and for the examination of which a grant was made at the Meeting of the British Association last year, is in the N.W. of Pembrokeshire, and in the immediate neighbourhood of the city of St. David's. The principal section occurs to the S. and S.E. of St. David's, along the north coast of St. Bride's Bay. It is, moreover, bounded by two well-marked faults, which run up in a N.-westerly direction, and which serve rather to isolate it. One only of these faults is marked on the Survey Map, that forming its eastern boundary, and which may be seen running up almost immediately behind the now well-known creek of Porth-y-rhaw, and which cuts off the upper and principal part of the Middle Lingula-flags, leaving only a few hundred feet to rest conformably upon the Lower Lingula-flags. The western fault occurs directly to the south of St. David's, at a place called Nun's Well, and just at the spot where the Conglomerate and lowest Cambrian beds are exposed on the coast line, so

that within the boundary of these two faults we have an exposed section of all the Lower Cambrian beds, the whole of the Lower Lingula-flags, and a part of the Middle Lingula-flags, following one another in true succession.

I have taken three parallel sections across the line of strike, as follows:—

1st. *Caerbwddy section*, to the west of Porth-y-rhaw, including nearly the whole of the Lower Cambrian beds exposed in this neighbourhood, and above 400 feet of the Lower Lingula-flags.

2nd. *Porth-y-rhaw section* runs along the east side of that creek, and includes the uppermost beds of the Lower Cambrians, and nearly the whole of the Lower Lingula-flags.

3rd, or *Cradle Rock section*, includes the remaining beds of the Lower Lingula-flags, and the Middle Lingula-flags as far as they are exposed here in true succession. It extends from a point inland of Porth-y-rhaw to the Cradle Rock—the latter an islet about midway from Porth-y-rhaw to the mouth of Solva Harbour. The first, or *Caerbwddy section*, cuts across the beds in a direction from N.W. by N. to S.E. by S., and includes about 1980 feet of conformable strata, comprising, in *ascending order*,—

Syenite.

Fine-grained shales, altered.

| | | feet. | |
|---|---|-------|-------------------|
| 1. Some Conglomerates (chiefly quartz pebbles in a purple base) | | 50 | } Lower Cambrian. |
| 2. Greenish sandstones in thin beds | | 280 | |
| 3. Purple sandstones, massive | | 860 | |
| 4. Upper Grey series .. | { A variable series. Yellowish sandstone and shale in thin beds, and grey grit, with purple bands in thick beds, a few beds of purple slate among them..... } | 360 | |
| | { a. Hard grey compact beds | 100 | |
| 5. Fossiliferous series (part of). | { b. Black and dark grey striped shales, with interbedded trap | 330 | } Upper Cambrian. |
| | | 1980 | |

The lowest third, or base of the fossiliferous series, is especially worth notice, as resembling very nearly in lithological character the immediately underlying Lower Cambrian beds, and distinguished from them *only by the absence of the purple bands*. It must be understood also that the absence of these bands by no means contradicts us in assigning these fossiliferous beds (No. 5 a) to the upper portion of the true Lower Cambrian or “*Harlech Grit*” series, since *many beds of the immediately underlying series are as free from purple colour as are any of these*. Purple and red beds, moreover, are not found to be favourable for the exhibition of organic traces. In the true purple beds (No. 3), and, indeed, in the whole of the Lower Cambrians of this district, worm tracks only have as yet been found, though it is to be hoped that the presence and true position of the *Oldhamia* will also be determined here ere long.

As we ascend from the coarse-grained compact beds already mentioned, the beds gradually become darker in appearance, of a finer grain, and more flag-like; the dip is very high, and often vertical.

The 2nd, or *Porth-y-rhaw section*, extends along the east side of that creek, in a direction from N. by E. to S. by W., includes about 700 feet of strata, nearly all fossiliferous, and shows the most perfect section of the Lower Lingula-flags anywhere exposed in this neighbourhood.

It begins in the Grey grit, or lowest fossiliferous beds (5 a), and upon

these, in ascending order, lie the Grey flag with black bands, and the true black beds (5 *b*), all well marked, and easily traced through their transitional states into one another. The passage, moreover, is quite perfect. The upper part of this section contains a thick bed or two of trap,—a circumstance common throughout the Lingula-flags in this district, as also occasionally in the Upper Grey series of the Lower Cambrian, though I have never seen it occur lower down. Mr. Salter has found it abundantly in the same beds in North Wales.

The 3rd, or *Cradle Rock* section, is a continuation of the second. The first beds in this section are the thick sandstone ones which terminated section 2; and upon these we have thin alternating beds of sandstone and shale of a dark grey colour, fossiliferous, and occupying a thickness of about 250 ft.; next, a series of beds still dipping in the same direction for about 450 ft., and composed of grey flaggy sandstone in thin beds, alternating at first with dark grey or black shale, and afterwards with yellowish shale. These last are evidently the base of the Middle Lingula-flags. After this the beds curve into a synclinal, which is again repeated about 600 ft. further on, so that but a portion only of the Middle Lingula series is in consequence exposed here. The general section thus sketched includes about 3000 ft. of conformable strata, and may well be looked upon as the typical section. Several other sections are also exposed inland, and along the coast, but in no case do we find one so continuous or uninterrupted by faults. Again, all others that I have examined, and which I may say include all the chief Cambrian masses exposed in N.W. Pembrokeshire, tend in every case to prove the facts exhibited clearly in this one. In most cases I have found the lithological characters of the beds, the thicknesses of the various series, and the fossils, when present, to tally in every particular with this section.

In section 2, or that of the east side of Porth-y-rhaw Creek, we meet with all the principal fossil types. By means of a fault, the purple-stained beds (4) are immediately followed by a set of beds, excepting in colour, apparently identical with them, hard Grey grit (5 *a*) in thick compact beds, which, as in the first section named, appear to be the top of the Lower Cambrian. In these beds, and within a few feet of true purple beds, I found a new *Paradoxides*, now named *P. Aurora*; associated with it a new *Conocoryphe*, of large size; a new *Theca*, a *Lingulella*, an *Obolella*, and fragments of *Agnostus* and *Microdiscus*. Unfortunately the first two are very fragmentary as yet, but there is quite enough to pronounce them new; and the *Paradoxides* is a very peculiar species. Fragments of these lowest fossils are also found in the creek to the west of Porth-y-rhaw, and through which I have taken section 1; and at two or three other places, where they hold exactly the same relation to the underlying purple beds, and to the series above. Though the purple band series have not yet yielded any definite traces of these higher forms of fossils, we are scarcely, I think, warranted in looking upon that as proof of their absence; neither is it, I think, likely that so rich, though limited, a fauna should come so suddenly into existence. About half a dozen only of the lowest beds are distinctly fossiliferous, the succeeding 150 ft. having yielded scarcely any traces as yet, though we may expect to find them.

These last beds are much lighter in colour, being a grey grit, and having only a few narrow dark bands. Rather abruptly the beds now become darker in colour and of a finer grain,—a dark-grey flag. In these we meet with *Parad. Hicksii*, not a new species, but one described already as *P. Forchhammeri*, from some unknown locality in North Wales, according to the testimony of my colleague, Mr. Salter, who has been trying for the last twenty years to

find out the true position and locality of this fossil. Associated with this second species of *Paralowides* are three or four other trilobites, two or three shells, &c.

From this point the beds become still darker in colour, black, flag-like, and slaty beds, full of fossils. A small cavern marks a good line for these highly fossiliferous beds, and here we meet with numerous new species, and even genera, which are not found elsewhere. The beds between the cavern and the traps are the chief repository of our species; and I will mention more particularly as occurring there two or three new species of Sponge, a Cystidean or two of undescribed form, several minute Brachiopoda, which range through a considerable space, and a host of trilobites, of which the more conspicuous genera are *Agnostus*, *Microdiscus*, *Conocoryphe* of four or five species, a new genus ?*Erinnys*, allied to *Harpides*, a new genus *Holcephalina*, and last of all, the great *Parad. Davidis*, already well known to British geologists. It sometimes attains the length of 18 inches.

The genus *Theca* here, as elsewhere, accompanies the primordial fossils; it is in considerable abundance, and of two or more species.

From a Table which contains the distribution of the fossils in these beds, and which has been carefully drawn up according to observations made by Mr. Salter and myself during the last three years, we are enabled to observe how that many of these species were very short-lived, whilst others on the contrary ranged through considerable spaces, more particularly the smaller species, such as *Agnostus*, *Microdiscus*, *Lingulella*, *Obolella*, &c. This Table also shows altogether 6 or 7 new genera of trilobites and about 16 species, and with brachiopod and pteropod shells, Cystidæ and Sponges, an addition within the last three years to British palæontology of about 33 new species.

Notes on the Sections and Fossils. By J. W. SALTER, A.L.S., F.G.S.

I FIND but little to say regarding the fossils, my friend and colleague having forestalled me, and completed in a masterly way the section I roughly sketched out in 1862. The district around St. David's will soon become popular, as it exhibits the most accessible section of the Cambrian rocks, Lower and Upper, to be seen anywhere in Wales. Those in the estuary of the Ffestiniog valley are perhaps more complete, but are not seen, except partially, in coast sections; and nowhere in one continuous series. Moreover, lying at lower angles of dip, they are extended over a much greater space.

Of the following list of 33 species—an ample fauna for the purpose—I may say at once, there are none common to other horizons of the palæozoic group, and as the thickness of the series is considerable, 3000 or 4000 feet, we only follow the precedent of older and better geologists by proposing a new name. The classic name of the district is Menevia, and we propose that the term 'Menevian' should stand for the Lower, as the 'Ffestiniog' of Prof. Sedgwick already stands for the middle and upper groups of the Lingula-flags. The 'Menevian' group, therefore, rests immediately on the 'Harlech' or Bangor group of Prof. Sedgwick, and passes imperceptibly into it.

The Cambrian groups will then stand as follows:—

| | | |
|--------------------------------|---|--|
| Upper Cambrian (Lingula-flags) | { | Tremadoc group (Upper and Lower). |
| | | Ffestiniog group (Lingula-flags). |
| | | Menevian group (Lower Lingula-flags). |
| Lower Cambrian | { | Harlech group (Grey grits and purple beds). |
| | | Longmynd group (sandstones and conglomerates). |

Fossils of the 'Menevian group,' or Lower Lingula-flag.

| | Upper Grey series.
Lower Cambrian. | Black Slate series.
Base of Upper Cambrian.
Lower Lingula-flags. |
|--|---------------------------------------|--|
| <i>Paradoxides Aurora</i> | — * | |
| — <i>Hicksii</i> | | |
| — <i>Davidis</i> | | |
| <i>Microdiscus punctatus</i> | | |
| <i>Agnostus scutalis</i> | | |
| — <i>Davidis</i> | — | |
| —, sp. | | |
| <i>Conocoryphe humerosa</i> | | |
| — <i>applanata</i> | | |
| — <i>variolaris</i> | | |
| — <i>bufo</i> | | |
| —, sp. | | |
| <i>Anopolenus Salteri</i> | | |
| — <i>Henrici</i> | | |
| <i>Erinnys (Harpides) venulosa</i> | | |
| <i>Holocephalina primordialis</i> | | |
| <i>Leperditia solvensis</i> | | |
| — <i>Buprestis</i> | | |
| <i>Discina Pileolus</i> | | |
| — <i>labiosa</i> | | |
| <i>Lingulella unguiculus</i> | | |
| —, sp. | | |
| —, sp. | | |
| <i>Obolella sagittalis</i> | | |
| — <i>maculata</i> | | |
| —, sp. | | |
| <i>Theca penultima</i> | | |
| — <i>corrugata</i> | | |
| —, sp. | | |
| <i>Cystidean (Protocystites)</i> | | |
| <i>Protospongia fenestrata</i> | | |
| — <i>diffusa</i> | | |
| —, sp. | | |

This list will surely be increased. But it may serve already to show the near resemblance the group bears to other parts of the Lingula-flag or Upper Cambrian series in some points, and the wide difference in others. *All the species* are distinct. Many of the *genera* are only known here at present, e. g. *Paradoxides*, *Microdiscus*, *Anopolenus*, *Erinnys*, *Holocephalina*, and the peculiar sponge, *Protospongia*. The Cystidean may be different from others. But we cannot yet prove this, though it seems likely.

In beds higher up in North Wales *Olenus* is found. But of this more hereafter.

The "Menevian group" is distinguished by possessing the largest and smallest of Trilobites—those with the most multiplied segments, and those with the fewest. *Paradoxides*, *Erinnys*, and *Olenus* are the opposites in every respect of *Agnostus* with 2, and *Microdiscus* with 4 segments to the body. Indeed *Erinnys* (if it can be thoroughly separated from *Harpides*, which we doubt) has nearly the greatest number of free segments known in the order, more than *Paradoxides*; but probably fewer than *Harpes*.

* The length of the lines indicates the range of the species, long or short, as the case may be.

We have here a larger proportion of blind Trilobites, and those without facial sutures, than in higher formations. *Agnostus*, *Microdiscus*, and *Erinnys* are destitute of facial suture, and probably of eyes. *Holocephalina* seems to have been furnished with very minute eyes, so far out as nearly to be lost. And *Anopolenus*, while it has immense eyes, has a most singular restriction in the development of the free cheeks, and is in many respects abnormal.

The Brachiopods are such as we were led to expect. Minute and almost rudimentary forms of *Lingulæ* and *Discinæ*, with some kindred genera, form, with *Theca*, the whole of the shells. The Sponge seems to be a peculiar form; yet not so different from the Silurian ones as at first supposed. The fibres are very rudimentary in structure. The Cystidean is as yet imperfectly known.

Perhaps the most curious point about this fauna is the greater resemblance it bears to the Bohemian primordial group than is borne by any other member of the Lingula-flag. The *Paradoxides* which mark several distinct horizons here, are not known in the Upper Lingula-flag. The species of *Conocoryphe* resemble Bohemian and Spanish types. *Erinnys* or *Harpides* is like the Bohemian species. *Holocephalina* resembles *Arionellus*, &c.

If from such scanty indications we may judge anything, it would be that the Bohemian primordial group represents our Lower, and not our Upper Lingula-flags. These last are rich in *Olenus*, a genus absent altogether from Bohemia, but abundant in Northern Europe. It is accompanied, according to Angelin, by *Paradoxides* in Sweden. But with us, the genera follow a very regular order. *Paradoxides* appears first, *Anopolenus* second, and then various species of *Olenus* last.

Several of the forms above catalogued (*Microdiscus*, *Erinnys*, &c.) are found in beds of the same age near Ffestiniog in North Wales; and the great *Paradoxides Davidis* occurs in black slates on the same horizon at the gold-mines of Dolgelly, North Wales (see Decades, Geol. Survey, No. 11, Pl. 10).

We have included in our list those species found in the uppermost grey beds of the Lower Cambrian; but all may for the present be included provisionally in our 'Menevian' group.

Report of the Lunar Committee for Mapping the Surface of the Moon.

By W. R. BIRT, at the request of the Committee, consisting of JAMES GLAISHER, F.R.S., Lord ROSSE, F.R.S., Sir JOHN HERSCHEL, Bart., F.R.S., Professor PHILLIPS, F.R.S., WARREN DE LA RUE, F.R.S., President of the Royal Astronomical Society, Dr. LEE, F.R.S., Rev. W. R. DAWES, F.R.S., Rev. T. W. WEBB, F.R.A.S., J. N. LOCKYER, F.R.A.S., H. S. ELLIS, F.R.A.S., and W. R. BIRT, F.R.A.S.

THE first object of the Committee appointed at Bath in the year 1864 was to prepare forms suitable for the registration of lunar objects, for recording original observations, for facilitating the formation of a catalogue, and for computing the coordinates of the positions of objects. The results of the labours of the Committee are now presented to the Association in the shape of Form No. 1, for recording observations; Form No. 2, for facilitating the arrangement of objects in a catalogue; Form No. 3, for recording the positions, extents, heights and depths, brightness and alignments of lunar objects, with descriptions, synonyms and references to existing authorities; and Form No. 4, for computing positions of the second order. The annexed form is that for recording general observations of the moon.

[Form No. 1.] *British Association for the Advancement of Science.**General Observations of the Moon, made at the**Observatory,**By**Telescope**Eye Piece*

| Year and Month. | Day. | Hour. | Subjects of Observation. | Estimate of Brightness. | Symbol of Reference. |
|-----------------|------|-------|--------------------------|-------------------------|----------------------|
| | | | No. | | |
| 1 | 2 | 3 | 4 | 5 | 6 |

This Form is intended to be bound in volumes for use in observatories. It contains the usual columns for registering the year, month, day and hour of observation, a wide column for the reception of the observations themselves, and two additional columns, one for the registration of the *brightness* of objects, the other for receiving a *symbol* of reference on which a word or two in explanation may be appropriate.

Whatever object may be the subject of observation, either physical or micrometrical, as soon after the observations as may be convenient, the proper symbol of reference which is described in Form No. 2 is to be inserted in the last column against the name or description of the object observed; and as Form No. 1 is intended as a chronological record of observations of all kinds, the entries in this column will indicate the proper sheets of Form No. 3, in which the data obtained by observation are to be entered. Employing a commercial simile, Form No. 1 is the day book, Form No. 3 the ledger, and Form No. 2 the directions for posting.

A vast amount of detail having reference to the moon's surface has been accumulating since the time of Hevelius, but up to the present period a systematic arrangement of the objects discoverable on the surface has not been attempted; for although Beer and Mädler in their "*Der Mond*" have arranged the descriptive part of their work in quadrants, commencing with the north-west and ending with the south-west, it embraces only the most conspicuous objects; numerous features, some even of large extent, are entirely passed over, and indeed those which have been noticed by Beer and Mädler form a very small portion of the objects that may be detected with a telescope even of small aperture, or an object glass of two or three inches diameter. It is also not a very easy matter to arrange objects on the moon's surface, inasmuch as they are unlike those celestial objects which have been arranged in catalogues. The fixed stars, double stars, variable stars, and nebulae find a natural arrangement in the order of right ascension; not so the objects on the moon's surface; it is true they are invariably situated with regard to the central meridian of *mean libration*, but to arrange them in the order of selenographical longitude east and west of the central meridian, it is necessary that the position of each should be rigorously determined, a work that still remains to be done, and it may be many years before it can be accomplished.

In order to meet this desideratum, the Committee have drawn up and issued the following Form (No. 2) for facilitating the arrangement of a catalogue by means of symbols; and in accordance with it more than 1000 objects are now symbolized and entered in Form No. 3.

[Form No. 2.] *British Association for the Advancement of Science.*—LUNAR
COMMITTEE.—TABLE OF AREAS.

Zones and Limiting Latitudes.

| Limiting
longitudes. | I. II.
0° to 5°. | III. IV.
5° to 10°. | V. VI.
10° to 15°. | VII. VIII.
15° to 20°. |
|-------------------------|-----------------------|------------------------|-----------------------|---------------------------|
| 0 to 5 | A ^{<i>α</i>} | A ^{<i>ζ</i>} | A ^{<i>λ</i>} | A ^{<i>π</i>} |
| 5 " 10 | A ^{<i>β</i>} | A ^{<i>η</i>} | A ^{<i>μ</i>} | A ^{<i>ρ</i>} |
| 10 " 15 | A ^{<i>γ</i>} | A ^{<i>θ</i>} | A ^{<i>ν</i>} | A ^{<i>σ</i>} |
| 15 " 20 | A ^{<i>δ</i>} | A ^{<i>ι</i>} | A ^{<i>ξ</i>} | A ^{<i>τ</i>} |
| 20 " 25 | A ^{<i>ε</i>} | A ^{<i>κ</i>} | A ^{<i>ο</i>} | A ^{<i>υ</i>} |
| 25 " 30 | B ^{<i>α</i>} | B ^{<i>ζ</i>} | B ^{<i>λ</i>} | B ^{<i>π</i>} |
| 30 " 35 | B ^{<i>β</i>} | B ^{<i>η</i>} | B ^{<i>μ</i>} | B ^{<i>ρ</i>} |
| 35 " 40 | B ^{<i>γ</i>} | B ^{<i>θ</i>} | B ^{<i>ν</i>} | B ^{<i>σ</i>} |
| 40 " 45 | B ^{<i>δ</i>} | B ^{<i>ι</i>} | B ^{<i>ξ</i>} | B ^{<i>τ</i>} |
| 45 " 50 | B ^{<i>ε</i>} | B ^{<i>κ</i>} | B ^{<i>ο</i>} | B ^{<i>υ</i>} |
| 50 " 55 | C ^{<i>α</i>} | C ^{<i>ζ</i>} | C ^{<i>λ</i>} | C ^{<i>π</i>} |
| 55 " 60 | C ^{<i>β</i>} | C ^{<i>η</i>} | C ^{<i>μ</i>} | C ^{<i>ρ</i>} |
| 60 " 65 | C ^{<i>γ</i>} | C ^{<i>θ</i>} | C ^{<i>ν</i>} | C ^{<i>σ</i>} |
| 65 " 70 | C ^{<i>δ</i>} | C ^{<i>ι</i>} | C ^{<i>ξ</i>} | C ^{<i>τ</i>} |
| 70 " 75 | C ^{<i>ε</i>} | C ^{<i>κ</i>} | C ^{<i>ο</i>} | C ^{<i>υ</i>} |
| 75 " 80 | D ^{<i>α</i>} | D ^{<i>ζ</i>} | D ^{<i>λ</i>} | D ^{<i>π</i>} |
| 80 " 85 | D ^{<i>β</i>} | D ^{<i>η</i>} | D ^{<i>μ</i>} | D ^{<i>ρ</i>} |
| 85 " 90 | D ^{<i>γ</i>} | D ^{<i>θ</i>} | D ^{<i>ν</i>} | D ^{<i>σ</i>} |
| | <i>a</i> | <i>b</i> | <i>c</i> | <i>d</i> |

| Limiting
longitudes. | IX. X.
20° to 25°. | XI. XII.
25° to 30°. | XIII. XIV.
30° to 35°. | XV. XVI.
35° to 40°. |
|-------------------------|-----------------------|-------------------------|---------------------------|-------------------------|
| 0 to 5 | A ^{<i>φ</i>} | E ^{<i>α</i>} | E ^{<i>ζ</i>} | E ^{<i>λ</i>} |
| 5 " 10 | A ^{<i>χ</i>} | E ^{<i>β</i>} | E ^{<i>η</i>} | E ^{<i>μ</i>} |
| 10 " 15 | A ^{<i>ψ</i>} | E ^{<i>γ</i>} | E ^{<i>θ</i>} | E ^{<i>ν</i>} |
| 15 " 20 | A ^{<i>ω</i>} | E ^{<i>δ</i>} | E ^{<i>ι</i>} | E ^{<i>ξ</i>} |
| 20 " 25 | A | E ^{<i>ε</i>} | E ^{<i>κ</i>} | E ^{<i>ο</i>} |
| 25 " 30 | B ^{<i>φ</i>} | F ^{<i>α</i>} | F ^{<i>ζ</i>} | F ^{<i>λ</i>} |
| 30 " 35 | B ^{<i>χ</i>} | F ^{<i>β</i>} | F ^{<i>η</i>} | F ^{<i>μ</i>} |
| 35 " 40 | B ^{<i>ψ</i>} | F ^{<i>γ</i>} | F ^{<i>θ</i>} | F ^{<i>ν</i>} |
| 40 " 45 | B ^{<i>ω</i>} | F ^{<i>δ</i>} | F ^{<i>ι</i>} | F ^{<i>ξ</i>} |
| 45 " 50 | B | F ^{<i>ε</i>} | F ^{<i>κ</i>} | F ^{<i>ο</i>} |
| 50 " 55 | C ^{<i>φ</i>} | G ^{<i>α</i>} | G ^{<i>ζ</i>} | G ^{<i>λ</i>} |
| 55 " 60 | C ^{<i>χ</i>} | G ^{<i>β</i>} | G ^{<i>η</i>} | G ^{<i>μ</i>} |
| 60 " 65 | C ^{<i>ψ</i>} | G ^{<i>γ</i>} | G ^{<i>θ</i>} | G ^{<i>ν</i>} |
| 65 " 70 | C ^{<i>ω</i>} | G ^{<i>δ</i>} | G ^{<i>ι</i>} | G ^{<i>ξ</i>} |
| 70 " 75 | C | G ^{<i>ε</i>} | G ^{<i>κ</i>} | G ^{<i>ο</i>} |
| 75 " 80 | D ^{<i>φ</i>} | H ^{<i>α</i>} | H ^{<i>ζ</i>} | H ^{<i>λ</i>} |
| 80 " 85 | D ^{<i>χ</i>} | H ^{<i>β</i>} | H ^{<i>η</i>} | H ^{<i>μ</i>} |
| 85 " 90 | D ^{<i>ψ</i>} | H ^{<i>γ</i>} | H ^{<i>θ</i>} | H ^{<i>ν</i>} |
| | <i>e</i> | <i>f</i> | <i>g</i> | <i>h</i> |

| Limiting
longitudes. | XVII. XVIII.
40° to 45°. | XIX. XX.
45° to 50°. | XXI. XXII.
50° to 55°. | XXIII. XXIV.
55° to 60°. |
|-------------------------|-----------------------------|-------------------------|---------------------------|-----------------------------|
| 0° to 5° | E π | E ϕ | I α | I ζ |
| 5 " 10 | E ρ | E χ | I β | I η |
| 10 " 15 | E σ | E ψ | I γ | I θ |
| 15 " 20 | E τ | E ω | I δ | I ι |
| 20 " 25 | E ν | E | I ϵ | I κ |
| 25 " 30 | F π | F ϕ | K α | K ζ |
| 30 " 35 | F ρ | F χ | K β | K η |
| 35 " 40 | F σ | F ψ | K γ | K θ |
| 40 " 45 | F τ | F ω | K δ | K ι |
| 45 " 50 | F ν | F | K ϵ | K κ |
| 50 " 55 | G π | G ϕ | L α | L ζ |
| 55 " 60 | G ρ | G χ | L β | L η |
| 60 " 65 | G σ | G ψ | L γ | L θ |
| 65 " 70 | G τ | G ω | L δ | L ι |
| 70 " 75 | G ν | G | L ϵ | L κ |
| 75 " 80 | H π | H ϕ | M α | M ζ |
| 80 " 85 | H ρ | H χ | M β | M η |
| 85 " 90 | H σ | H ψ | M γ | M θ |
| | i | k | l | m |

| Limiting
longitudes. | XXV. XXVI.
60° to 65°. | XXVII. XXVIII.
65° to 70°. | XXIX. XXX.
70° to 75°. | XXXI. XXXII.
75° to 80°. |
|-------------------------|---------------------------|-------------------------------|---------------------------|-----------------------------|
| 0° to 5° | I λ | I π | I ϕ | N α |
| 5 " 10 | I μ | I ρ | I χ | N β |
| 10 " 15 | I ν | I σ | I ψ | N γ |
| 15 " 20 | I ξ | I τ | I ω | N δ |
| 20 " 25 | I $\omicron$ | I υ | I | N ϵ |
| 25 " 30 | K λ | K π | K ϕ | O α |
| 30 " 35 | K μ | K ρ | K χ | O β |
| 35 " 40 | K ν | K σ | K ψ | O γ |
| 40 " 45 | K ξ | K τ | K ω | O δ |
| 45 " 50 | K $\omicron$ | K υ | K | O ϵ |
| 50 " 55 | L λ | L π | L ϕ | P α |
| 55 " 60 | L μ | L ρ | L χ | P β |
| 60 " 65 | L ν | L σ | L ψ | P γ |
| 65 " 70 | L ξ | L τ | L ω | P δ |
| 70 " 75 | L $\omicron$ | L υ | L | P ϵ |
| 75 " 80 | M λ | M π | M ϕ | Q α |
| 80 " 85 | M μ | M ρ | M χ | Q β |
| 85 " 90 | M ν | M σ | M ψ | Q γ |
| | n | o | p | q |

| Limiting
longitudes. | XXXIII. XXXIV.
80° to 85°. | XXXV. XXXVI.
85° to 90°. | |
|-------------------------|-------------------------------|-----------------------------|-----------------------------------|
| 0° to 5° | N ^ζ | N ^λ | |
| 5° " 10° | N ^η | N ^μ | |
| 10° " 15° | N ^θ | N ^ν | |
| 15° " 20° | N ^ι | N ^ξ | N. Latitude } Quadrant I. |
| 20° " 25° | N ^κ | N ^ο | W. Longitude ... } |
| 25° " 30° | O ^ζ | O ^λ | |
| 30° " 35° | O ^η | O ^μ | N. Latitude } Quadrant II. |
| 35° " 40° | O ^θ | O ^ν | E. Longitude ... } |
| 40° " 45° | O ^ι | O ^ξ | |
| 45° " 50° | O ^κ | O ^ο | S. Latitude } Quadrant III. |
| | | | E. Longitude ... } |
| 50° " 55° | P ^ζ | P ^λ | |
| 55° " 60° | P ^η | P ^μ | S. Latitude } Quadrant IV. |
| 60° " 65° | P ^θ | P ^ν | W. Longitude ... } |
| 65° " 70° | P ^ι | P ^ξ | |
| 70° " 75° | P ^κ | P ^ο | |
| 75° " 80° | Q ^ζ | Q ^λ | |
| 80° " 85° | Q ^η | Q ^μ | |
| 85° " 90° | Q ^θ | Q ^ν | |
| | r | s | |

TABLE for facilitating the Arrangement of a Catalogue of Lunar Objects.

The preceding Table is based upon the following considerations:—

It is proposed to divide the visible hemisphere of the moon into four quadrants, as in Beer and Mädler's map, which are numbered as follows:—N. W. I., N. E. II., S. E. III., S. W. IV.

Each of these quadrants to be subdivided into sixteen grand divisions, as under, distinguishing the space between

| of long. | of lat. | | of long. | of lat. | |
|---------------|----------------------------|----|---------------|-----------------------------|----|
| 0° to 25° and | 0° to 25° by the letter A. | | 0° to 25° and | 50° to 75° by the letter I. | |
| 25° " 50° " | 0° " 25° " | B. | 25° " 50° " | 50° " 75° " | K. |
| 50° " 75° " | 0° " 25° " | C. | 50° " 75° " | 50° " 75° " | L. |
| 75° " 90° " | 0° " 25° " | D. | 75° " 90° " | 50° " 75° " | M. |
| 0° " 25° " | 25° " 50° " | E. | 0° " 25° " | 75° " 90° " | N. |
| 25° " 50° " | 25° " 50° " | F. | 25° " 50° " | 75° " 90° " | O. |
| 50° " 75° " | 25° " 50° " | G. | 50° " 75° " | 75° " 90° " | P. |
| 75° " 90° " | 25° " 50° " | H. | 75° " 90° " | 75° " 90° " | Q. |

These grand subdivisions to be still further subdivided into spaces of 5° of longitude and 5° of latitude. Each of the nine grand subdivisions included between 0° and 75° of longitude and 0° and 75° of latitude will thus be divided into twenty-five smaller spaces, and distinguished successively by the twenty-four small letters of the Greek alphabet in their order, leaving one division blank, which will always be the last, in each of the nine divisions.

In each of the spaces included between 0° and 75° of longitude and 75° and 90° of latitude, designated by the letters N, O, P, there are only fifteen smaller spaces, which are distinguished by the first fifteen small letters of the Greek alphabet.

In each of the spaces included between 75° and 90° of longitude there are only fifteen portions or areas of 5° of longitude and 5° of latitude, and these are distinguished by the three of the first five Greek letters in each corresponding group of five in the same parallels of latitude.

By this arrangement objects situated in any area of 5° of longitude and 5° of latitude may be readily designated, and very readily so after a little practice, every space on the moon being thus classified and designated by a Roman Capital with a small Greek character as the index: thus an object situated between 40° and 45° of longitude and 25° and 30° of latitude will be designated by F^ξ , while another situated between 20° and 25° of longitude and 20° and 25° of latitude will be designated by A without the Greek index. It is intended to distinguish the separate objects by the Arabic numerals, thus, $A^{\delta 6}$.

It is intended to collect in Tables various information appertaining to each object—as its selenographical coordinates, degree of reflective power, height or depth as the case may be, accompanied by references to more detailed descriptions, previous notices, drawings, and maps, including photographs, each separate Table being headed with one of the symbols in the annexed Table. Thus the Table which is intended to include *all* objects between 5° and 10° of longitude and 10° and 15° of latitude in Quadrant I. will be headed I. A^μ ; in Quadrant II., II. A^μ ; in Quadrant III., III. A^μ ; and in Quadrant IV., IV. A^μ .

When a sufficient number of objects are entered in the above-mentioned Tables, it is intended to arrange them in zones of 5° of latitude, each zone consisting of two parts, west and east, the dividing line being the central meridian, 0° of longitude, mean libration. The zones are arranged as in the preceding Table; in which the numerals indicating zones I. and II., each from 0° to 5° of latitude north and south of the equator; III. and IV., each from 5° to 10° of latitude also north and south of the equator, and so on, to zones XXXV. and XXXVI., are placed over the respective latitudes which determine them. By this arrangement zones I., III., V., VII., &c. belong to the north part of the moon's visible hemisphere in Quadrants I. and II., and zones II., IV., VI., VIII., &c., to the south part of the moon's visible hemisphere in the Quadrants IV. and III.

In those instances in which the longitudes of objects exceed 90° , being brought into view by changes of libration, the nomenclature is carried on; for example, an object having 93° W. longitude and 3° N. latitude is designated by the symbol I. D^δ .

In respect to the use of this Form, the *Mare Crisium* may be adduced as an example of employing the symbols for designating objects. The surface of this *Mare* is extended upon twelve areas, as follows:—

| | | | |
|--------------|--------------|------------|---------------|
| IC $^\xi$ | IC $^\nu$ | IC $^\mu$ | IC $^\lambda$ |
| IC $^\tau$ | IC $^\sigma$ | IC $^\rho$ | IC $^\pi$ |
| IC $^\omega$ | IC $^\psi$ | IC $^\chi$ | IC $^\phi$ |

and upon these areas various craters and other objects are found. Beer and Mädler give ten craters on their large map, and on the small one, published in 1837, Mädler gives fifteen additional, but small craters. In the year 1863 I ascertained with the Hartwell Equatorial two additional craters to those on the large map, also a small pit-like marking west of Picard. During the year 1865 the existence of several more has been ascertained, so that now at least forty-nine are known, exclusive of fourteen of the fifteen additional craters given by Mädler in 1837*.

* The fourteen craters here alluded to require *identification*; ten of them are situated, according to the map, south of IC $^{\mu 1}$ and IC $^{\nu 3}$, near the S.W. border of the *Mare Crisium*, one to the west of and in a line with IC $^{\mu 1}$ and IC $^{\nu 3}$, and the rest south of Picard.

The following Table exhibits the mode in which the existence of an object, when once ascertained, may be readily recorded, and the object itself so designated that very little, if any, difficulty may be experienced by future observers in identifying it. It is intended that the symbols appropriated to the objects described shall be *unalterable*, $IC^{\lambda 1}$, for example, always pointing out the crater Picard. The forty-nine objects symbolized in the Table have been entered in Form No. 3.

Craters on and near the *Mare Crisium*, arranged in order of Areas of 5° .

| No. | Symbol. | Description. | Date of discovery. | Discoverer. |
|------------------|-------------------|--|--------------------|-----------------|
| IC^{λ} . | | | | |
| 1. | $IC^{\lambda 1}$ | Schröter's "Picard." | | |
| 2. | $IC^{\lambda 2}$ | An ancient ring near the S.E. border.... | | Schröter. |
| 3. | $IC^{\lambda 3}$ | A deep crater N.W. of $IC^{\lambda 2}$ (d. B. & M.). | | Cassini. |
| 4. | $IC^{\lambda 6}$ | An ancient ring between Picard and the E. Pass. | Aug. 31, 1863. | Birt. |
| 5. | $IC^{\lambda 7}$ | A minute crater near E. Pass | Oct. 28, 1863. | Webb. |
| 6. | $IC^{\lambda 8}$ | A minute crater between $IC^{\lambda 6}$ and $IC^{\lambda 3}$. | Oct. 28, 1863. | Webb. |
| 7. | $IC^{\lambda 11}$ | A small crater on E. branch of Schröter's forked ridge. | Oct. 5, 1865. | Knott and Birt. |
| 8. | $IC^{\lambda 12}$ | A small crater W. of $IC^{\lambda 2}$ | Nov. 4, 1865. | Knott. |
| 9. | $IC^{\lambda 13}$ | A small crater W. of $IC^{\lambda 12}$ | Nov. 4, 1865. | Knott. |
| 10. | $IC^{\lambda 14}$ | A small crater N.W. of $IC^{\lambda 13}$ | Nov. 4, 1865. | Knott. |
| IC^{μ} . | | | | |
| 11. | $IC^{\mu 1}$ | A small crater between Prom. Agarum and Schröter's forked ridge. | Jan. 6, 1794. | Olbers. |
| 12. | $IC^{\mu 2}$ | A small crater W. of $IC^{\lambda 1}$ (Picard) | Dec. 12, 1864. | Knott. |
| 13. | $IC^{\mu 3}$ | A crater on the E. branch of Schröter's ridge. | Oct. 5, 1865. | Knott and Birt. |
| 14. | $IC^{\mu 5}$ | A minute crater S. of $IC^{\mu 2}$ | Dec. 12, 1864. | Knott. |
| 15. | $IC^{\mu 6}$ | A crater on the W. branch of Schröter's ridge. | Oct. 5, 1865. | Knott and Birt. |
| 16. | $IC^{\mu 11}$ | A small crater near the S. border of M. Crisium. | Nov. 4, 1865. | Knott. |
| 17. | $IC^{\mu 12}$ | A small crater E. of $IC^{\mu 11}$ | Nov. 4, 1865. | Knott. |
| 18. | $IC^{\mu 13}$ | A small crater N. of $IC^{\mu 11}$ | Nov. 4, 1865. | Knott. |
| 19. | $IC^{\mu 14}$ | A small crater E.N.E. of $IC^{\mu 12}$ | Nov. 4, 1865. | Knott. |
| 20. | $IC^{\mu 15}$ | A small crater on the W. branch of Schröter's forked ridge. | Nov. 4, 1865. | Knott. |
| IC^{ν} . | | | | |
| 21. | $IC^{\nu 3}$ | A small crater between $IC^{\mu 1}$ and Prom. Agarum. | Jan. 6, 1794. | Olbers. |
| 22. | $IC^{\nu 5}$ | A small crater just E. of Prom. Agarum. . | April 29, 1865. | Dawes. |

| No. | Symbol. | Description. | Date of discovery. | Discoverer. |
|-----------------|-----------------|---|--------------------|-----------------|
| IC^{π} . | | | | |
| 23. | $IC^{\pi 1}$ | Beer and Mädler's "Picard A." | | |
| 24. | $IC^{\pi 2}$ | Beer and Mädler's "Picard B." | | |
| 25. | $IC^{\pi 4}$ | A small crater nearly N. of $IC^{\lambda 1}$ (Picard) | Aug. 8, 1865. | Ingall. |
| 26. | $IC^{\pi 5}$ | A minute crater nearly N. of $IC^{\lambda 1}$ (Picard) | Oct. 7, 1865. | Bird. |
| 27. | $IC^{\pi 6}$ | A crater in the interior of $IC^{\pi 1}$ | | Schmidt. |
| 28. | $IC^{\pi 7}$ | A crater on the exterior W. wall of $IC^{\pi 1}$. | Oct. 5, 1865. | Knott and Birt. |
| 29. | $IC^{\pi 8?}$ | On the N. extremity of the ridge W. of the E. pass (B. & M.). | | Cassini. |
| 30. | $IC^{\pi 9}$ | A small crater S. of $IC^{\pi 1}$ | Nov. 4, 1865. | Knott. |
| 31. | $IC^{\pi 10}$ | A small crater E. of $IC^{\pi 1}$, near E. border of M. Crisium. | Nov. 4, 1865. | Knott. |
| IC^{ρ} . | | | | |
| 32. | $IC^{\rho 1}$ | A small crater N.W. of $IC^{\lambda 1}$ (Picard) | Feb. 28, 1865. | Dawes. |
| 33. | $IC^{\rho 2}$ | A crater on Schröter's ridge N. of the fork. | Nov. 4, 1865. | Knott. |
| 34. | $IC^{\rho 5}$ | A small crater near the N. part of Schröter's forked ridge. | April 29, 1865. | Dawes. |
| 35. | $IC^{\rho 6?}$ | A small crater W. of $IC^{\rho 5}$ | April 29, 1865. | Dawes. |
| IC^{σ} . | | | | |
| 36. | $IC^{\sigma 1}$ | A ring on the W. part of the surface | Oct. 7, 1865. | Birt. |
| 37. | $IC^{\sigma 2}$ | A small crater N. of Prom. Agarum | April 29, 1865. | Dawes. |
| 38. | $IC^{\sigma 3}$ | A small crater S.E. of $IC^{\sigma 2}$ | April 29, 1865. | Dawes. |
| 39. | $IC^{\sigma 4}$ | A small crater between $IC^{\sigma 2}$ and $IC^{\sigma 3}$. | Nov. 4, 1865. | Knott. |
| 40. | $IC^{\sigma 5}$ | A small crater E. of $IC^{\sigma 4}$ | Nov. 4, 1865. | Knott. |
| IC^{τ} . | | | | |
| 41. | $IC^{\tau 2}$ | A small crater near the W. border of the M. Crisium. | April 29, 1865. | Dawes. |
| 42. | $IC^{\tau 3}$ | A small crater N. of $IC^{\tau 2}$ | Nov. 4, 1865. | Knott. |
| IC^{χ} . | | | | |
| 43. | $IC^{\chi 1}$ | A crater near the N.E. border (F. B. & M.). | | |
| 44. | $IC^{\chi 2}$ | A smaller crater S.W. of $IC^{\chi 1}$ (B. & M.). | May 3, 1794. | Schröter. |
| 45. | $IC^{\chi 3}$ | A crater N. of $IC^{\chi 1}$ | May 3, 1794. | Schröter. |
| 46. | $IC^{\chi 4}$ | A small crater S.W. of $IC^{\chi 3}$. | | |
| IC^{ψ} . | | | | |
| 47. | $IC^{\psi 1}$ | A ring near the N.W. border (B. & M.). | | |
| 48. | $IC^{\psi 3}$ | A small crater N.W. of $IC^{\psi 1}$ | May 3, 1794. | Schröter. |
| 49. | $IC^{\psi 7}$ | A small crater between $IC^{\psi 1}$ and $IC^{\psi 3}$. | May 3, 1794. | Schröter. |

Note.—Nos. 5, 29, and 35. The symbols of these craters are queried, as the positions of the craters require to be more accurately determined.

In order to arrange the objects seen on the moon's surface in a systematic and orderly manner, with a view to the formation of a catalogue, we must in the first instance adopt some means by which we may so *fix* an object observed that it may ever after in *all* time be sufficiently identified by *all* future observers. Hevelius laid the foundation of this process, although the nomenclature of his successor, Riccioli, has been grasped firmly by the astronomical mind, so that the larger features and craters are now so readily recognized, and in one way or another brought before the attention of astronomers, that we should as soon expect to lose sight of Sirius, Lyra, Arcturus, Capella, Regulus, or any of the brighter stars, as to experience any difficulty in identifying Copernicus, Tycho, Plato, Hipparchus, Ptolemæus, Gassendi, the Mare Crisium, the Mare Nectaris, or any of the more conspicuous craters and regions of the moon; but as there are smaller stars in the heavens requiring the aid of catalogues for their exact identification, especially when used as comparison stars in the observations of small planets, comets, &c., so in several questions connected with lunar physics, there are small objects, forming in many instances portions of the larger features, that require to be particularly specified, especially when questions of *supposed* change obtrude themselves and claim a hearing, a small crater or apparently insignificant mountain being adduced as evidence. In the present state of selenography we cannot say positively of any object "it is new." All questions of this kind that may be raised must be left in doubt. Astronomical juries cannot agree on their verdicts. A great authority thus expressed himself:—"Although not in a position myself, after twenty-five years' close observations of this kind, to bring forward even one certain example of new formation, when the question is confined to crater forms, yet I am far from disputing the fact of the existence of new formations on the moon"*. Close and systematic record, as well as close and unremitting observation, is necessary to be able to settle a question of this kind, and the record should embrace the results of the observations of *all* observers. The symbols alluded to under the head of Form No. 2, to be inserted in column 2 of Form No. 3 (see page 296), appear to be suitable for accomplishing this object; more than 1000 lunar objects being absolutely *fixed* as to all future identification by their means, provided certain elements, hereafter to be named, are ascertained.

The next step in the formation of a catalogue is the determination of the exact positions of the objects symbolized. This has been done with more or less accuracy in numerous instances, the coordinates (latitudes and longitudes) of many objects having been settled from observation, nevertheless these already settled points will not appear numerous; as the process of symbolizing proceeds, they will be found on the 1440 sheets of Form No. 3 requisite for drawing out the catalogue, few and far between; and in order to increase them, the use of the micrometer, or of a meridional instrument, will be essential. There are *three* methods by which these points may be fixed. First, by differences of right ascension and declination between the preceding or following, and upper or lower limbs of the moon and the object, the latitude and longitude of which is to be determined. This method was employed by M. Bouvard at the Royal Observatory of Paris in 1808 to 1810. From a series of 124 such differences in each direction, M. Nicollet determined the selenographical latitude and longitude of the crater Manilius, and also the amount of the moon's libration. Second, by measures taken with the micrometer between the apparent east and west and north or south limbs

* See Julius Schmidt's communication to the 'Astronomische Nachrichten,' translated by Lynn, on page 299.

of the moon and the object. This method, proposed by Encke, has been employed by Lohrmann and Beer and Mädler. Third, by measuring the lengths and position-angles of *two* lines on the moon's surface; one joining *two* objects, the coordinates of which have been already determined by one of the methods above mentioned; the other joining *one* of the same two objects, and a third, the position of which is to be determined. The difference of the position-angles will give the angle between the two lines from which, with the lengths of the two lines, the position of the third object may be known. Beer and Mädler employed this method for the determination of positions of the second order.

The latitudes and longitudes of lunar objects require to be expressed by the rectangular coordinates X and Y in parts of the moon's semidiameter, which is regarded as unity. This is for the purpose of properly inserting them in a map on the orthographical projection. The latitude of an object, which we may call β , being its distance from the moon's equator, X is equal to the sine of the latitude or β , and the expression for X becomes $X = \sin \beta$. The longitude of an object, which is designated λ , is its distance east or west from the moon's central meridian on the same projection, which is proportional to multiplying the sine of the longitude into the cosine of the latitude; for on the equator the longitudes are simply proportional to the sines, the distance of an object 30° E. longitude, for example, from the centre of the moon's disk on the equator is equal to the natural sine of 30° or 0.5; but at 10° of latitude and 30° of longitude, an object is nearer the moon's central meridian in the above-named proportion, and the expression for Y becomes $Y = \sin \lambda \cos \beta$, which, when computed, gives 0.49240, and we have $X = 0.17365$, $Y = 0.49240$. In Form No. 3 provided by the Committee the column (2) for the reception of the symbols is followed by four (3, 4, 5, and 6), for inserting the values of the coordinates X and Y, and the latitudes and longitudes.

Next to *position* comes *size* or extent of lunar objects, which may be expressed in two ways, and for which the Committee has provided two columns, one (7) headed "Mag.," a contraction for magnitude, the other (8) "Miles," in which it is intended to enter the values of the diameters of lunar craters in English miles, and also, as suggested by W. De la Rue, Esq., in French kilometres. As both these elements, *magnitude* and *diameters in miles*, must be ascertained by measurement—estimation being altogether too rough—a word or two on the method of effecting it may be acceptable. It is intended to express the magnitude by a number showing the ratio as to size which the crater, mountain, or spot, dark or light as it may be, bears to one chosen as a standard (Dionysius for example); any given measure of the standard, which may be called "*s*"—however the measures may vary from time to time, arising from differences of distance, effect of libration, differences in the lines measured, and other circumstances—is considered equal to unity, and if the measures of any other spots, *made on the same evening*, be designated *a, b, c, d, &c.*, the magnitude *m* of each will be determined by the simple formula $m = \frac{a}{s}$, $m' = \frac{b}{s}$, $m'' = \frac{c}{s}$, and so on.

For the column (8) headed "Miles," it is necessary to measure across the crater, but as it has been *assumed* that most of the lunar craters are strictly circular, and the experience which has been gained relative to the standard Dionysius, appears to point, in this instance at least, to some irregularity of form, the determinations of the extent in miles can only be considered as approximate. Beer and Mädler give a list of 149 objects, the diameters of

which are expressed in German miles. This list in “Der Mond” is preceded by a formula for computing the diameters from observations, dependent on the moon’s distance from the earth, as expressed by parallax, the moon’s altitude above the horizon, and the position of the object with regard to the visible centre of the moon’s disk.

The computation of the heights of mountains requires, according to Beer and Mädler’s method, three measured elements, viz., the length of the shadow, the distance of the summit from the terminator or boundary between light and darkness, and also its distance from one of the horns or the extremity of the enlightened part of the moon north or south. These measured data, combined with the longitude and parallax of the sun, and the longitude, latitude, and parallax of the moon, enable the observer to determine the true length of the shadow in parts of the moon’s radius, having previously ascertained two important angles, viz., that which the terminator makes with the line joining the horns, and that which measures the sun’s altitude above the horizon (at the moon) of the object measured. After having ascertained the length of the shadow in parts of the moon’s radius, it is not difficult to determine the height of the object.

Schröter has given, in his ‘Selenotopographische Fragmente,’ numerous instances of measured mountains, both isolated and on the rings of craters, the results being expressed in Parisian feet. Beer and Mädler have given a list of 1095 measurements of heights expressed in French toises, and Mädler, on the small map published in 1837, gives 236 expressed in Parisian feet. For the results of the measurements converted into English feet two columns (9 and 10) have been appropriated in Form No. 3.

Two columns (11 and 12) are also provided for *brightness*, or “Reflective Power,” one headed *Estimated* the other *Measured*. The observer of the moon’s surface cannot fail to be struck, not only with a great variety of tints in which

[Form No. 3.] *British Association for the Advancement of Science.*—(LUNAR COMMITTEE.)

Positions, Extent, Heights, Depths, Brightness, and Alignments of Lunar Objects, with Description, Synonyms and References to existing Records and Authorities.

| Number
in
Catalogue. | Reference.
of
Symbol | Coordinates. | | | Extent. | | Heights and depths
according to | | Brightness. | | Alignment. | Description | Synonyms and References. | | | | De la
Rue. | |
|----------------------------|----------------------------|--------------|------|-------|---------|--------|------------------------------------|---------------------|-----------------|----------------|------------|-------------|--------------------------|-----------|---------------------|-------------------|---------------|-----------|
| | | X. Y. | Lat. | Long. | Mag. | Miles. | Schröter. | Beer and
Mädler. | Esti-
mated. | Mea-
sured. | | | Beer and
Mädler. | Schröter. | Beer and
Mädler. | Lohrmann.
Map. | | Sections. |
| | | | | | | | | | | | | | | | | | | |

Notes.

the presence of colour is unmistakeable, from a deep blackish grey to an almost dazzling whiteness, but also with a gradation of brilliancy, some spots shining with a vividness far exceeding others, which, although they may be regarded as "bright," are yet dull as compared with those that are more vivid. Some of these spots are supposed to vary in *intensity of brightness*, while others may be regarded as tolerably steady; and if some amount of interest attaches to the smaller features of the moon's surface, as bearing upon the subject or question of change, no less amount of interest will be found to characterize the range of brilliancy, especially when changes which cannot altogether be referred to an alteration in the direction of the incident rays, obtrude themselves on our notice. In the time of Schröter, if not earlier, an attempt was made to chronicle these gradations of brilliancy by adopting a decimal scale, in which the absolute absence of light was regarded as zero, and the brightest spot on the moon's surface was denominated 10°. Schröter, Lohrmann, and Beer and Mädler adopted this notation, and the first column, under the general heading "Brightness," is intended to receive the results of a careful examination of all their estimations, as well as the results of future eye-estimations of the brightness of lunar objects.

It is quite evident that *estimations* of any element can never command that reception which instrumental determinations are able to do. With this view a column has been inserted for receiving the measures of brightness or reflective power, and it was thought that, by means of an instrument such as that described by Mr. Dawes at the Meeting of the Royal Astronomical Society, June 9, 1865 (see *Monthly Notices*, vol. xxv. p. 229), the gradations of brightness might be measured with facility. The use of the instrument, as recommended by Mr. Dawes, requires that the feature under examination should be isolated by means of the solar eyepiece, thus shutting out all rays from surrounding objects. Doubtless a graduated series of brightnesses may be obtained in this way which would possess a great amount of value; but one feature has presented itself in some trials which were made to ascertain the deepest tint that would quite obscure the brightest spot "Aristarchus." It was obscured, and perfectly invisible, upon a ground of which the *collective power of reflexion* was able to pierce the dark-tinted glass, and not only to pierce it as a *dull* light, but also to show the outlines (somewhat indistinctly) of the brighter and darker spaces on which the brighter spots *then visible* were situated (not unlike the appearance of the night-side of the moon illuminated by earth-shine a few days before and after change), the larger darker spaces coming out with the same intensity as the larger brighter spaces, so that upon settling the zero-point, the brighter spaces would be positive and the darker negative; thus while a zero might be obtained for a *collective reflective power*, it would be difficult to express by the same notation the absolute brightness of the smaller brighter spots, or the absolute darkness of the smaller darker spots. This being the case, it is possible a modification of the homochromascope may be employed with advantage. (See *Monthly Notices of the Royal Astronomical Society*, vol. xxii. p. 11.)

One very important circumstance that may present itself to the observer, and one that will assume a much greater degree of importance in the estimation of the selenographer, engaged in symbolizing and cataloguing objects, is the *unmistakeable identification* of the smaller features, such as minute craters, mountains, rills, soft ridges, &c. A simple mode of recognition and identification presents itself in the alignment of objects, and for this two objects, one on *each* side of the object to be identified, will suffice. If, however, it should

so happen that one on each side cannot be conveniently chosen, three objects (including the one to be identified) in a line will contribute perhaps quite as much to finding the object sought. The column (13) in Form No. 3, headed *Alignment*, is intended to receive *three* symbolical references, *one* being the object catalogued under the symbol heading the sheet with the Arabic numeral at the commencement of the line, for example; II : IIE^{π⁴} : IIE^{ρ²}, in which IIE^{π⁴} represents the crater Piazzzi Smyth, and this aligns with IIE^{π¹} and IIE^{ε²}.

The wide column (14) headed "*Description*" scarcely needs a remark. The descriptions of objects are intended to be as brief as possible, noting principally their relative positions, &c. with regard to other objects.

In order that a catalogue, such as the one now in progress, should be perfectly efficient and accomplish the object intended, it is manifest that *nothing* should be omitted, nor should it be compiled *hastily*; the labours of all previous selenographers should find a place, all synonyms should be inserted, and references made to existing maps and drawings. With this view a portion of each symbolic sheet of Form No. 3 is devoted to the reception of such synonyms and references; the first column (15) being intended for references, in Roman numerals, to a special catalogue of objects, the descriptions of which have been drawn up from careful observation with the telescope.

The second column (16) in this department of Form No. 3 is intended to receive an appropriate symbol, which at once indicates whether the object be a crater, mountain, mountain-chain, rill, low ridge, lucid streak, or other feature. For this purpose the following symbols are employed:—

Craters and depressions are indicated by a small italic character, with an index number, both inclosed in parentheses thus, (*b*¹).

Confluent craters are thus shown, (*c*¹ : *c*²).

Ancient rings thus, (*e*⁵).

Valleys thus, *a*||¹.

Mountains are indicated by a small Roman character, with an index number, both inclosed in parentheses thus, (*a*¹).

Mountain-chains are indicated in the same way, with a dash under the letter thus, (*a*²).

These letters are not to be applied arbitrarily. To each zone of latitude of 5° a character, Roman or Italic, is especially appropriated. One of these letters (Italic) is printed at the foot of each column of symbols, under the head of "Zones and limiting latitudes" in Form No. 2, ranging from *a* to *s*, they are to be used thus:—If a mountain be found in zone XV. or XVI., viz., 35° to 40° N. or S. latitude in any quadrant, the symbol pointing it out to be a mountain is (*h*), the numbering being consecutive, a catalogue of mountains will ultimately be formed; the same may be said of craters or any other feature.

Low ridges are indicated by an Arabic numeral, inclosed in brackets, thus [2].

Lucid streaks in the same way with a dash under, thus [6].

Lucid spots by a number with a cipher below, thus [8₀].

Dark streaks are shown by the number having two dashes, *one* above, the other below, thus [4].

Dark spots are shown by the addition of a cipher to the left and above, thus [⁰6].

Rills are indicated by the symbol 1 .

It is expected that by the employment of these symbols the distinguishing character of the feature catalogued may be seen at a glance. It is intended that the numbering should proceed consecutively, as objects are added to the separate catalogue in which Roman Numerals are employed to enumerate the features observed.

The communication of J. F. Julius Schmidt, Director of the Observatory at Athens, to the 'Astronomische Nachrichten' bears so greatly on the subject of observing the smaller features, that I am induced to give *in extenso* the translation of it, by W. T. Lynn, B.A., F.R.A.S., of the Royal Observatory, Greenwich.

"Of late years, several observers in England have occupied themselves very perseveringly with *the special study of the moon's surface*, and have occasionally arrived at conclusions leading to the belief that newly formed mountain ranges are now being discovered upon the moon. Although not in a position myself, after twenty-five years' close observations of the kind, to bring forward even one certain example of new formation, when the question is confined to crater-forms, yet I am far from disputing the fact of the existence of *new formations* upon the moon. I do not, however, seek them so much amongst the craters, of which thousands of smaller ones, wanting in LOHRMANN and MÄDLER, are now from time to time being detected, but have for about fifteen years past directed my attention especially to the *rills*, of which I have newly discovered a *very great number*, and amongst these several of remarkable form, easy to be recognized, which have not been seen since the time of Schröter. With regard to the *craters* noticed by Messrs. Webb and Birt, in Marius, in Mersenius, near Delisle, b, &c., I have known these since the year 1846, and am in possession of various drawings of them. As importance is being attached to these individual isolated craters (for which there are indeed good grounds), it may be here mentioned that I detected on the 2nd and 4th of January in the present year, in the inner surface of Picard A (*Mare Crisium*), a small crater, which, together with two others in the northern wall, has escaped all the observers up to this time, although in a region frequently and particularly scanned both by Schröter and myself.

"As objects repaying careful investigation, I recommend the extremely remarkable *rill-systems* near Ramsden, and a little westerly of Aristarchus, discovered by me on January 4, 1849, at Bonn, and on May 10, 1862, at Athens. Any one experienced in this department of observation who will consider, under favourable circumstances, the twelve or thirteen extraordinary *rills* and *crater furrows*, will perceive for himself how small is the probability that phenomena so remarkable should for so many years have escaped the notice of practised observers, merely on account of external circumstances.

"Athens, Jan. 5, 1865."

(Signed) "J. F. JULIUS SCHMIDT."

The indefatigable Schröter accumulated a large amount of information relative to the moon's surface, which he published in two quarto volumes, entitled "Selenotopographische Fragmente." It is principally arranged as topographical notices, including, as we have before remarked, numerous measurements of mountains, craters, &c., with estimations of brightness, and accompanied with numerous engravings of the sketches and drawings which he made from time to time. Every conspicuous object, and in many cases very small objects in peculiar situations, have upon the engravings letters referring to a description of the objects in the text. These delineations and descriptions are increasing daily in value, and it is easy to see that labours such as those of Schmidt, recorded in the above article, are themselves

increased in value by the existence of records such as Schröter's, Lohrmann's, and Beer and Mädler's. Lohrmann's sections, with the text, may be placed in the same category as Schröter's, and his map, with 500 *reference-numbers*, but no text, including a very large amount of detail, furnishes material by which the selenographer may confirm his observations, or by means of it, objects may be indicated that may have been overlooked, or possibly may even be new. Beer and Mädler's large map is of the same character as Lohrmann's, but with this advantage, notices of the features on the map (to which reference-letters, Roman, Italic, or Greek, are attached) are to be found in the text, affording, with the results of previous labours in the same field, a large amount of existing material to catalogue; for it is evident that features found on the maps and drawings, and referred to in the text, had a *bonâ fide* existence, and were subjects of observation at the three several epochs. The later and smaller map of Mädler is also valuable for reference. In order to ensure the insertion of these objects in the catalogue, four columns (17, 18, 19, and 20), having suitable headings, are appropriated to references to these authorities, the reference-letters and figures being given when available; and in other instances, where the objects are found in the maps or engravings, but without any reference-letters or figures, a dash (—) is inserted, the absence of a dash against any object indicating that it is not to be found in the records of the selenographer whose name is at the head of the column.

Of all the aids that we possess to the attainment of a valuable and extensive knowledge of the moon's surface, none are calculated to afford such accurate results, so far as mapping, symbolizing and cataloguing are concerned, as photography. The large number of negatives produced by Warren De la Rue, Esq., and the enlargement of them both on glass and paper, must become of much valuable assistance in the progress of this work. The true relative positions of objects are capable of being very readily determined, and when reference is made to the normal position of mean libration,—the photograph taken on October 4, 1865, at 9^h 0^m 4^s mean time, at Cranford being a standard in this respect,—the photographs will contribute in no small degree to accurate mapping and symbolizing; other important data are also obtainable by their means. In order to ensure a careful comparison of all existing records with the results of photography, a column (21) is inserted, and headed "De la Rue," in which every object found on the photographs is indicated by a dash (—).

[Form No. 4.] *British Association for the Advancement of Science.*—
(LUNAR COMMITTEE.)

Form for computing the Positions of Lunar Objects (the Second Order).

| Symbol
of
Reference. | Symbol
of
Reference. | Position
$\angle$ | ψ or $\angle$ of
inclination
AC to AB. | Microm.
Rev. | Diff. of +
and —
Readings. | m' Mea-
sured
Distance. | m'' True
Distance. |
|----------------------------|----------------------------|----------------------|---|-----------------|----------------------------------|-------------------------------|-----------------------|
| | | ° ' " | ° ' " | r | r | r | r |

$$\tan \phi = \frac{Y - Y'}{X - X'}$$

$$1 = \frac{X - X'}{\cos \phi}$$

$$\frac{X =}{X' =}$$

$$\frac{Y =}{Y' =}$$

$$\text{Log. } (X - X')$$

$$\text{Log. } (Y - Y') \quad \text{, , ,}$$

$$\text{Log. } \tan \phi$$

$$\phi =$$

$$\text{Log. } \cos \phi$$

$$\text{Log. } 1$$

$$1 =$$

| | | | | | | |
|---------------------------------|-------|-------|-------|-------|-------|-------|
| | | | | | | |
| Log. Sec. ψ | | | | | | |
| Log. m' | | | | | | |
| Sum=Log. m'' | | | | | | |
| Log. l | | | | | | |
| Ar. co. Log. m | | | | | | |
| Sum=Log. AC | | | | | | |
| | ° / " | ° / " | ° / " | ° / " | ° / " | ° / " |
| ϕ | | | | | | |
| ψ | | | | | | |
| $\phi - \psi$ | | | | | | |
| Log. Cos ($\phi - \psi$)..... | | | | | | |
| Log. AC | | | | | | |
| Sum=Log. x' | | | | | | |
| x' | | | | | | |
| X | | | | | | |
| Sum= x =Sin β | | | | | | |
| | ° / " | ° / " | ° / " | ° / " | ° / " | ° / " |
| β =Latitude | | | | | | |
| Log. Sin ($\phi - \psi$)..... | | | | | | |
| Log. AC | | | | | | |
| Sum=Log. y' | | | | | | |
| y' | | | | | | |
| Y | | | | | | |
| Sum= y | | | | | | |
| Log. x | | | | | | |
| Log. Sec. β | | | | | | |
| Sum=Log. Sin λ | | | | | | |
| | ° / " | ° / " | ° / " | ° / " | ° / " | ° / " |
| λ =Longitude | | | | | | |

Notes.

This Form is intended to aid in the computation of positions of the second order, which are determined, first, by measurements of the angle of position and distance between two points the positions of which have been determined by measurements of the first order (see Beer and Mädler's 'Der Mond,' pp. 40-45), and secondly by the angle of position and the true distance between one of the points of the first order and the point whose position is to be determined. The calculation is performed according to the following formulæ:—

Let AB (fig. 1) be the measured side of a triangle of the first order, l

on the moon's surface." At the time of the appointment of the Committee, I had made 291 series of observations, which were commenced as early as January 6, 1860.

During the year, between the Meetings of the Association at Bath and Birmingham, I have lost no opportunity of increasing the number of observations, and have made 124 series, which are equivalent to 124 nights of observation. These observations amounted to 416 series at the time of the Meeting at Birmingham; and, with 33 made since, now amount to 449. The whole are of various kinds, including physical examinations of several portions of the moon's surface, particularly of the crater "Plato," every crater, mountain, ridge, plain, or other feature that had been the subject of observation being distinctly specified in the observations. Numerous metro-metrical measurements for the magnitudes and positions of objects are also included. The whole of these observations are in process of being examined, reduced, and classified, and the results entered in Form No. 3.

The series of observations between January 5, 1860, and September 22, 1863, amounting to 176, were made with two telescopes. The one most extensively used in London was the Sheepshank's Telescope No. 5, lent by the Council of the Royal Astronomical Society expressly for the purpose of lunar researches. The diameter of the object glass is 2.75 inches. It is furnished with three powers, is mounted on a tripod, and has vertical and horizontal motions in altitude and azimuth. The observations not made with this instrument were made during various visits to Hartwell with the Equatorial of 5.9 inches aperture.

Early in January 1863, the Council of the Royal Society voted a sum of money for the construction of a telescope with an object glass of $4\frac{1}{4}$ inches diameter, under the superintendence of Warren De la Rue, Esq., suitable for the work in which I was then and am still engaged. This was completed in September 1863, and has since been employed in the observations, stated visits during the period that has elapsed between June 1863 and September 1865 having been made to Hartwell, at Dr. Lee's request, for the purpose of continuing the observations with the Hartwell Equatorial.

At the time of the appointment of this Committee, I had drawn up *preliminary* forms for the insertion of various data appertaining to objects on the moon's surface, a large amount being scattered over the works of Schröter, Lohrmann, and Beer and Mädler. It was then, and still is, my intention to increase these data by observation, and enter them in Form No. 3, each object, as before mentioned, being designated by a symbol. When the Association met at Bath in 1864, 386 separate objects had been entered in the preliminary Forms; 62 of these have since been transferred to Form No. 3, which, with 399 entered independently, make 461 objects entered in Form No. 3, the total number of objects now catalogued being 785*.

Early in December 1863 I conceived the idea of forming a catalogue of lunar objects, as I had met with considerable difficulty in recording many, especially the smaller features, in such a way as readily to identify them afterwards. At that time I had accumulated a number of observations, first, of the crater 'Plato' and its immediate neighbourhood, and afterwards of the N.W. portion of the *Mare Imbrium*, including all the mountains which are scattered over its surface, which have been named the 'Teneriffe' Mountains, to commemorate 'an astronomer's experiment,' as recorded in Professor Piazzi Smyth's work entitled 'Teneriffe.'

In the course of my observations several remarkable features of the moon's

* Now augmented to 1032.

surface have been presented to my notice; and here I would remark that observations of this kind differ considerably from ordinary astronomical observations; many of the features appear to be exceedingly evanescent, and can only be detected on rare occasions, and these at considerable intervals, the one from the other; a very slight alteration in the direction of the incident or reflected ray suffices to render an object invisible which a few hours before might have been seen with distinctness, and good measures of it obtained. Webb has alluded to this where he says, in his 'Celestial Objects for common Telescopes,' p. 54, "As the angle of illumination increases, a fresh aspect of things creeps in, and this aspect is such that we may sometimes catch the whole, sometimes a portion, sometimes nothing of many a familiar feature." It is therefore important to seize the opportunity when presented for examining carefully a district the illumination of which is such as to bring out in strong relief the most minute features discernible. During a period of nearly seven years' observations, there are some features that I have seen only four or five times, and some only once. The rill-system on the S.W. of Triesnecker I have seen favourably only on one occasion, nearly twelve months since, and that after waiting many months to obtain it. After carefully scanning the surface of the moon, should an opportunity of the kind now alluded to be presented, no time should be lost, nor trouble spared in obtaining as correct a record as possible of the details visible. The following are a few of the instances in which remarkable features have been brought out with extraordinary distinctness, so much so as to mark out distinctly the boundaries of individual regions.

The Plain of Dionysius.—"On the morning of January 18, 1865, between 5 and 7 A.M., the subject of observation was the great Rill of Ariadæus discovered by Schröter, and described, under this head, by Beer and Mädler. It was well situated, both as regarded visual and illuminating angles; and I noticed that south of the rill, between Ariadæus and Silberschlag, the surface, which forms a somewhat extensive plain, is slightly depressed, much in the same way as the surface on one side of the Straight Wall is lower than the other, with this difference—the rill of Ariadæus appears to have resulted from a *crack*; and throughout the length above specified the depth of the rill is plainly perceptible by its shadow. The depressed plain south of the rill is extensive; the four portions of it are symbolized, and in progress of entry in Form No. 3.

The Valley J. J. Cassini.—"In the course of Mr. Webb's correspondence, that gentleman has communicated an account of the recovery of one of Schröter's valleys, named by him J. J. Cassini, which, although appearing on Beer and Mädler's map, does not bear the name appropriated by Schröter.

On the morning of the 9th of February, 1865, I had an opportunity of comparing Schröter's drawing of J. J. Cassini with the moon; and although the weather prevented that full examination which I desired to make of the region, yet the general accuracy of Schröter's drawing was unmistakeable. The state of libration was such as to bring the objects into full view with less foreshortening; and although the form of the valley J. J. Cassini was not precisely as Schröter has given it, yet the general outline and the neighbouring craters fix Schröter's drawing to the part of the moon which he describes in his text; accordingly Beer and Mädler's statement, to the effect that Schröter's drawing is irreconcilable with the surface of the moon, appears to be without foundation*.

* This statement of Beer and Mädler appears to have originated from Schröter misnaming some craters in the neighbourhood.

The Table Land—Terra Photographica.—A few months ago Warren De la Rue, Esq., presented to the Committee an enlarged photograph of the moon (in four compartments), taken a few days after the first quarter, and directed the attention of Dr. Lee and myself to an elevated tract surrounded by the craters Cysatus, Curtius, Zach*, De Luc, Maginus, and Clavius, which he had discovered during the progress of his photographic experiments . . . It is proposed, in accordance with Mr. De la Rue's suggestion, to designate this Table Land 'Terra Photographica' (De la Rue). I have carefully compared the region with Lohrmann's and Beer and Mädler's maps, and find a portion of it very imperfectly represented by Beer and Mädler, with some of the coordinates apparently misplaced. I have also obtained two series of observations of its physical character. Under ordinary states of the atmosphere, a few craters appear on its surface; but on August 1, 1865, at Hartwell, the surface of the plain was seen to be pitted with numerous small craters; and at a still later period I found that it consisted of a depressed basin, with highly elevated rugged land abutting on Clavius, and an interesting mountain-chain. Beer and Mädler describe another mountain-chain, which I have not seen, nor does it appear prominently on the photograph.

The great Rill of Ariadæus.—The Rev. T. W. Webb refers in his work on Celestial Objects to a minute prolongation of this rill through the portion of the *Mare Tranquillitatis* near Sabine and Ritter, detected by Gruithuisen and Kunowsky; a small portion only was seen by Beer and Mädler. I succeeded in observing it on October 20, 1864, and have seen it since. It has also been seen on two or three occasions since October 1864 by Mr. Freeman at Mentone, in the Alpes Maritimes. Mr. Freeman has traced it to the group Ritter, Sabine, &c.

Among the observations of an instrumental character, I may mention some "that are differential of the second order, and which have reference to five groups now under systematic observation, both physically and instrumentally, as the state of illumination and other circumstances may allow, viz., the *Picard* group, the *Posidonius* group, the *Dionysius* group, the *Gassendi* group, and the *Triesnecker* group, each crater (or in some cases mountains within them) forming a central point; the angles and distances of each measured object being referred to a standard line, the coordinates of the two extremities having been determined by Beer and Mädler.

APPENDIX.

Translation of a Letter from the Director of the Observatory at Athens, J. F. Julius Schmidt, to Mr. W. R. Birt, London.

Your favour of the 23rd of September with which you honoured me is in my possession. I beg leave to answer your inquiry at once and in general, partly to show a mark of my sympathy for the interest you take concerning the topography of the moon, partly to make known to you and others the limits within which I have been occupied on the same object during a quarter of a century.

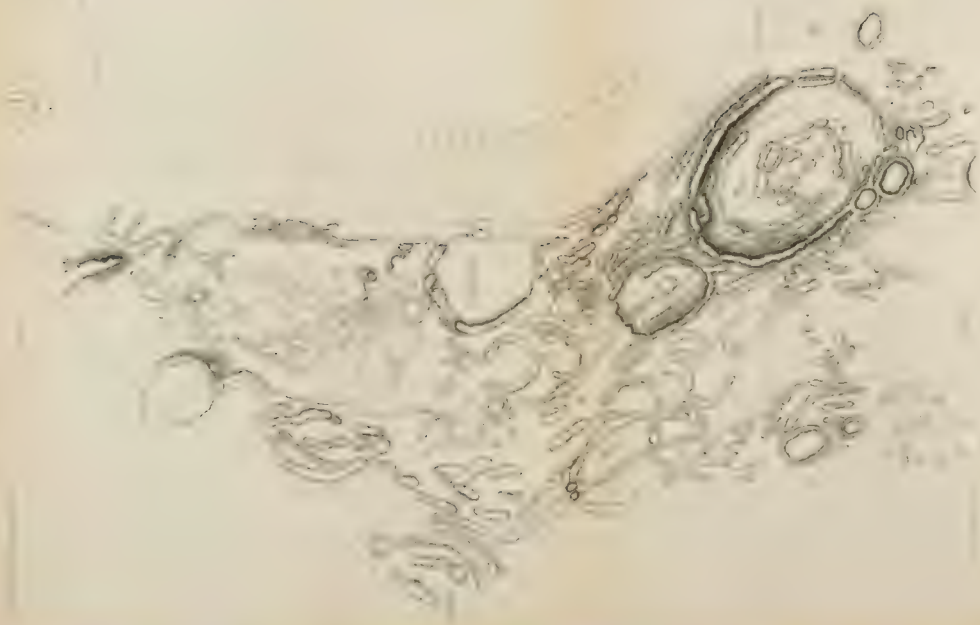
Passing over in silence my observations before the year 1842, I allude only to those which afford a topographical interest, and that are at present of some utility to me. Since June 1842 I could employ more powerful telescopes, and the sketches of detailed landscapes of the moon were obtained

* A crater between Zach and De Luc, perfectly visible in the photograph, but not on Beer and Mädler's map, forms part of the boundary of the "Terra Photographica." It is proposed to name it "Pollock, C.B."

partly at Hohenfeld, near Hamburg, and partly with the instruments of the observatory in that town. In the year 1845 I observed the moon but seldom, at the observatory at Bilk, near Dusseldorf. From 1846 to 1853 I have obtained at Bonn, and from 1853 to 1858 at Olmutz, many sketches; and with the refractor of the observatory at Olmutz I made and reduced 4000 micro-metrical measures of the altitudes of the mountains of the moon. In the interim I was twice so fortunate as to be able to apply refractors of the first class to the moon, by the kindness of Encke and Bruhns in Berlin (1849), and by the favour of Secchi in Rome (1855). Since 1860 I have continued these labours at Athens, partly because the very defective condition of this observatory is such that I could not participate in greater researches, or in those which appear more important at the present day. Perceiving, in January 1865, that I could not with satisfaction continue to neglect the mass of accumulated material, I considered it necessary to unite all my sketches in *one* great picture or plan; and I resolved at once to undertake that laborious work, without contemplating any publication. I selected a scale *double* that of the charts of Lohrmann and Mädler, giving my general chart, consisting of four folios, a radius of 3 feet, or about 2 metres diameter. This is now, with the assistance of my original sketches (nearly 1000), so far accomplished that the positions of the principal objects are laid down; and even in the landscapes near the limb but little is wanting. The chart exhibits already a considerable progression, and will probably be completed in two or three years. I chose the method of those authors, and took for points of the first and second order the data of Mädler and Lohrmann. The whole detail is based upon my own observations only.

The edition of Lohrmann's works was transferred to me from the publishers in Leipzig in the year 1854. The copper plates of all the twenty-five sections, with the exception of part of the shading, are completed, and I possess already a perfect copy. In the text to this chart I shall give a critical comparison with Mädler. Both in their way form well-executed charts for the selenographical local determinations, the proper and true basis of the more modern selenography of which Tobias Mayer laid the first foundation. Let us continue in trying, by the aid of more powerful telescopes, to represent the topography of the yet undelineated details of the surface of the moon, without, however (so far from setting a determinate limit), being able to see the end of such a work; it is as if from the ordinary determinations of place of the brighter stars down to the eighth magnitude one passed on to that of the stars in the Milky Way.

The study of the rills has particularly occupied me during the last fifteen years. The resemblance of numerous transformations and combinations of the rills and craters, has led me to the opinion that *all* rills present only volcanic phenomena, like all the rest of the moon. The study of the topography of our satellite will at once become very important for our geology. But it is a great error to believe that a survey once or twice of a mountain of the moon would entitle us to make certain comparisons or to arrive at certain conclusions. I find, after many years' minute observations, that at present it is prudent to avoid all speculations, and at first and before all things to establish an extended topography in conformity with our present means, free from contracted views, and so far exact and searching that we may hope thereby to give satisfaction to a remote posterity. That was also the opinion of Alexander von Humboldt, with whom I had often, from 1853 to 1856, communications on the subject. I myself have never been in possession of sufficient means to produce anything *important* for selenography,



and have been obliged to content myself with small contributions; but I abandon not the hope that I shall yet be enabled to make observations with *great* instruments.

Respecting the rills, I have now ready for printing a small pamphlet, in which are classified, up to February 1865, all those known to me. I hope to get it published in Leipzig. It contains 425, and these are divided in the following order:—

| | | | | |
|-------------------|----------|------------|-----|--------|
| From 1787 to 1801 | Schröter | discovered | 11 | rills. |
| „ 1823 „ 1827 | Lohrmann | „ | 75 | „ |
| „ 1832 „ 1841 | Mädler | „ | 55 | „ |
| „ 1847 „ 1848 | Kinau | „ | 6 | „ |
| „ 1842 „ 1865 | Schmidt | „ | 278 | „ |

Since that time I have discovered thirty or forty new rills. I point out as particularly remarkable the systems I observed in 1849–1862 near Ramsden and Aristarchus. The rills near the southern capes of the Apennines, Hyginus, Ariadaeus, and Sabine, are in connexion with that of Goclenius, as rills are existing in the plain near Torricelli. I enclose only a few slight sketches of remarkable rills, which, in case they should not yet be known to English astronomers, may give occasion to future researches. Those who are in possession of large telescopes should not neglect to make drawings of craters of the most minute kind, which are visible even in very small and well-limited regions, as the craters in Plato, Archimedes, Hevelius, Gassendi, Mersenius, Marius, &c.

Less important appears to me the study of such disturbed formations as Maginus and Longomontanus, because here we may *never* arrive at certain conclusions, for *all* the territory appears to consist only of craters of the smallest kind. As other objects of a rigorous and searching examination, I mention those little craters, crater-rows, crater-rills, that, situated in the interior of the ring mountains, form the limits of the plain and the beginning of the wall mountain. Here the eruptive forms have issued, as it were, out of cracks, and in parts of considerable and high mountains, where two mountain-masses, approaching each other, form a narrow valley, or a sharp corner. Just as important is the parallelism of many little craters, where they, as on Etna, cover the exterior of the walls of the mountains. Among such forms, spoken of to the fullest extent of the word, I class such bodies as Copernicus, with his many hundred neighbouring craters. But in a more limited sense, however, I comprehend examples, such as the craters outside of the north wall of Newton, where the wall mountains, covered with craters, slope against the south-east wall of Moretus. But everywhere a keen and unprejudiced course of observation will indicate that rills are only crater-rows in a particular modification, as the innumerable transformation-forms prove, and as Mädler first pointed out.

In the climate of Hellas (still more so in that of the more southern isles), so favourable for astronomical observations of every kind, many of the most important problems would in a short time be solved, if a practised observer, completely free from hypothetical views, were furnished with the necessary means.

S.

Athens, October 6th, 1865.

In illustration of this memoir, Herr Schmidt has forwarded a drawing (Plate IX.) of the rills west of the *Mare Serenitatis*, from Posidonius to a point south of Littrow.

Postscript.—Since the above Report was drawn up, an outline Map of the Moon, of 100 inches in diameter, has been commenced, and is now in progress. The positions of 105 points of the first order, as given in Beer and Mädler's 'Der Mond,' pp. 77, 78, form the basis of measurement for all the features discernible upon the photograph taken by Warren De la Rue, Esq., on October 4th, 1865, a short time before contact with the Earth's shadow, and when the apparent disk was not far from a state of mean libration. In this Map every important feature of the Full Moon will be laid down from measurements on the photograph referred to the equator and central meridian.

Report of the Committee on Standards of Electrical Resistance.

The Committee consists of Professor Williamson, Professor Wheatstone, Professor W. Thomson, Professor Miller, Dr. A. Matthiessen, Mr. Fleeming Jenkin, Sir Charles Bright, Professor Maxwell, Mr. C. W. Siemens, Mr. Balfour Stewart, Dr. Joule, and Mr. C. F. Varley.

THE Committee has the pleasure of reporting that the object for which they were first appointed has now been accomplished.

The unit of electrical resistance has been chosen and determined by fresh experiments; the standards have been prepared, and copies of these standards have been made with the same care as was employed in adjusting the standards themselves; seventeen of these copies have been given away, and sixteen have been sold.

The chief work of the Committee this year has been done by Dr. A. Matthiessen. Last year's Report announced the completion of the experiments determining the resistance in absolute measure of a certain coil of German-silver wire. Taking this coil as the basis, Dr. Matthiessen, assisted by Mr. C. Hockin, prepared ten standards, each expressing the British Association unit of electrical resistance; two of these standards are coils of platinum wire, two are coils of wire drawn from a gold-silver alloy, two are coils of wire drawn from a platinum-iridium alloy, and the remaining two are tubes of mercury.

The wires employed in the coils are from 0.5 millim. to 0.8 millim. diameter, and range from one to two metres in length. They are insulated with white silk, and are wound round a long hollow bobbin of brass. The wires are imbedded in solid paraffin, and enclosed in a thin brass case, which allows the coils to be plunged in a bath of water by which their temperature may be conveniently regulated and observed. Two short copper terminals project from the case and are forked at their ends, so that they may be connected with the Wheatstone's balance in the manner recommended by Professor W. Thomson, avoiding the error due to the possible resistance of connexions. The mercury standards consist of two glass tubes about three-quarters of a metre in length.

These ten standards are equal to one another and to the British Association unit, at some temperature stated on the coil or tube, and lying between $14^{\circ}5$ and $16^{\circ}5$ C.

None of them, when correct, differ more than 0.03 per cent. from their value at $15^{\circ}5$ C.

In the choice of the material, of which the standards are constructed, the

Committee have been much assisted by the experiments on permanency made by Dr. Matthiessen.

Silver and copper were found to alter in their resistance simply by age. German silver was also found to alter in some cases.

These materials had therefore to be rejected. Gold appears constant, but owing to its low specific resistance a considerable length would have been required, unless a wire had been adopted of very small diameter. This was not thought desirable, for several reasons; any slight decay or injury in the surface of a small wire would cause much greater alteration in the resistance than the same injury to a large wire. A small wire would be more liable to mechanical injury, and would be much more rapidly heated by the passage of currents. The Committee having rejected small wires for these reasons, thought it unnecessary to incur the expense of a large and thick gold wire. The great change of resistance caused by a change of temperature furnished another reason for rejecting gold and other pure metals. One pair of standards was, however, made of platinum, which appeared the most suitable of all the pure metals. Platinum and the three alloys named appear all to be very constant, that is to say, their resistance is not altered by age, or even by being subjected to considerable heat and recooled.

These materials also possess considerable mechanical strength; they are not easily injured by chemical action, they have considerable specific resistance, and that resistance, in the case of the three alloys, changes little with a change of temperature.

It is of course impossible to say with certainty that their resistance will not vary with time, but it is most unlikely that the resistance of all will vary in the same ratio. If, therefore, as is hoped, the eight coils made of such different materials retain their relative values, some confidence may be felt in the permanency of the unit.

Some additional security is given by the power of reproducing the unit, if lost, by chemical means, or by fresh experiments on absolute electro-magnetic measure, although neither of these means at present appear to give such perfect accuracy as would be secured by the permanency of a material standard. Fresh absolute experiments of the kind described in previous Reports would hardly reproduce the same value much within one part in a thousand, and Dr. Matthiessen, as appears from last year's Report, is not very sanguine of obtaining a better result than this by chemical means. Thus a difference exists in Dr. Siemens's and Dr. Matthiessen's reproduction of a unit by means of mercury, as pointed out in last year's Report. It is of course probable that differences of this kind will in time disappear, and Mr. Siemens fairly points out that the discrepancy mentioned in last year's Report, between coils made from a very old and those made from a new determination of the mercury unit, affords no criterion of the accuracy with which mercury can now be used as a means of reproduction. Dr. Siemens was the first person who produced numerous sets of coils accurately adjusted; and although unable to recommend the adoption of his unit of resistance, the Committee once more take an opportunity of expressing their sense of the high value of Dr. Siemens's researches on the reproduction of units by means of mercury. Dr. Siemens is confident that a unit can be and has been reproduced by means of mercury with an accuracy of 0.05 per cent.; but meanwhile, the chief security for the permanency of the unit consists in the preservation of standards constructed in various ways and of various materials.

The mercury tubes furnish an additional security. A molecular change may occur in the wires, that is to say, they may become of harder or softer

temper, they may be injured chemically in course of time by some action on their surface; it is just possible that the repeated passage of currents may alter them in some way, although we have no reason as yet to expect such an alteration.

Mercury is free from all these objections. Its temper cannot vary, and as it would be purified afresh on each occasion, it will be chemically uninjured.

On the other hand, some fresh dangers may occur in its use. The tubes themselves may alter in time, or the mercury may not always be absolutely pure. Absolute security cannot be had, but the choice of a variety of materials will probably prevent any serious alteration from occurring without detection.

The copies which have been issued are similar in form to the standard coils, but the terminals are simple thick copper rods, intended to be dipped in mercury cups. The security given by this mode of connexion is sufficient for all ordinary purposes, and it was feared that the use of the double terminals might not be everywhere understood. The platinum-silver alloy has been used in all the copies. Wire made of this alloy is very strong and ductile. It can, for instance, be drawn down to a diameter of 0.0002 inch. Its resistance is not permanently altered even by a great change of temperature, and even annealing hardly affects it. Moreover, the change in its resistance due to a variation of 1° Centigrade is at ordinary temperature only 0.032 per cent., being less than that of any other alloy tested. It is also a commercial alloy, which has been long used by dentists; and Dr. Matthiessen points out, as a curious coincidence, that many commercial alloys coincide with proportions indicating peculiar electrical properties. *Vide* Appendix A.

The copies of the standard have been supplied for £2:10s. in boxes with small mercury cups for the connexion, and with a printed direction for use inside the box, stating the temperature at which that particular coil is equal to 1 B.A. unit.

A satisfactory proof of the accuracy with which these coils have been prepared was given by four independent observations, by practical electricians not belonging to the Committee, of the relative value of four distinct B.A. coils, and four independent standards issued by Dr. Siemens.

These four observations gave of 10456, 10455, 10456 and 10457 as the measure of Siemens's standard, in terms of the B.A. units, proving the accuracy both of Dr. Siemens's work and that of the Committee.

Twenty coils were to be distributed gratis, and seventeen have actually been given away to the following recipients:—

The Directors of Public Telegraphs in—

| | | |
|-------------|------------------|--------------------|
| France. | Spain. | Prussia. |
| Austria. | Italy. | Sweden and Norway. |
| Belgium. | Portugal. | Russia |
| India. | Victoria. | |
| Queensland. | New South Wales. | |

Also to Professor Kirchhoff, Dr. Joule, Professor Neumann, and Professor Weber.

Three remain for distribution. Sixteen have been sold. Dr. Faraday, on behalf of the Royal Institution, was the first purchaser.

In distributing the coils, it was thought best not to give them to institutions, where they would probably have laid on a shelf useless and unknown, but rather to distribute them widely, where they might become available to practical electricians.

The new unit has been actually employed to express the tests of the Atlantic Telegraph Cable. Mr. Varley promises that the unit shall in future be the basis of the coils used by the Electric and International Company.

Sir Charles Bright promises that the unit shall be exclusively used by the British and Irish Magnetic Telegraph Company.

A standard has been supplied to the Royal Engineers at their request. The head of the Telegraph Department in India has introduced the unit, and there is little doubt that the British Colonies generally will adopt it.

More time will certainly be required to introduce it on the Continent. The French Government has taken no steps to ensure its introduction, but M. Blavier, the official editor of the '*Annales Télégraphiques*,' has promised his cordial support to the Committee. The Austrian Government has promised to use the coils experimentally, and the German gentlemen to whom coils were given have promised to give their best assistance.

Coils have also been bought by the managers of two large telegraphic establishments in Switzerland, at Neuchatel, and Zurich. There is therefore reason to hope that the unit may come into extensive use.

When standard galvanometers, Leyden jars, and electrometers are issued, all forming part of one coherent and necessary system, it is probable that the B.A. unit will be found so much more useful than any other as to supplant them entirely. Until these further issues take place, it will only be adopted either by men who can understand the advantage given by it in calculation, or by electricians who feel confidence in the recommendations of your Committee.

With a view to experiments which will allow of these further issues of electrical units, a large electro-dynamometer has been designed, and is nearly complete. Graduated Leyden jars, with air as the only dielectric, have also been designed and are nearly ready for use. An apparatus for the determination of the quantity called v in Appendix C of the 1863 Report is in the same condition. Prof. W. Thomson has for some time had ready apparatus for absolute measurements of electrical effects, but his connexion with the Atlantic Cable has suspended his work. Dr. Joule promises fresh measurements of the mechanical coefficient of heat, and has only been delayed by the want of experiments which other members of the Committee must previously complete.

In conclusion, the Committee are at last able to report one positive result, but they feel that much more remains to be done.

APPENDIX A.—*On the Construction of the Copies of the B.A. Unit.*

By A. MATTHIESSEN, F.R.S., and Mr. CHARLES HOCKIN.

THE standard coil used in the experiments at King's College, described in the Report of your Committee for 1864, was put into our hands about last Christmas, in order that unit-coils representing a resistance equal to ten million metres per second in Weber's electro-magnetic system might be made from it.

Since that time several unit-coils have been made and issued.

We propose to state the method by which these coils were made, and the reasons for choosing the particular alloy which has been adopted for the conductor. The alloy referred to is composed of 66 per cent. of silver and 33 of platinum.

This alloy possesses many properties which fit it for the use to which it has been put.

As to its electrical properties :—

I. It alters less in electrical resistance with changes of temperature than any other known alloy.

The importance of this point needs hardly to be enforced on any one who has used resistance-coils.

The increment in the resistance of the alloy due to a change of temperature from 0° to 100° C. is only 3.2 per cent.

II. The conducting-power of the alloy is very low, and is about one-half that of German silver.

III. The conducting-power of the alloy is not altered by baking, that is by exposing it to a temperature of about 100° C. for several days.

This is a property of great importance, for it has been observed that those conductors which do not alter by baking, do not alter by age either. The experiments by which this has been established have been published in former Reports.

IV. The conducting-power of a wire of the alloy is little altered by annealing.

Further, the alloy does not oxidize by exposure to the air; it does not readily alloy with mercury; it makes a sufficiently pliable wire, and can be drawn to a very great degree of fineness. Dentists have made considerable use of it in consequence of its good chemical and mechanical properties*. Of this alloy, twenty unit-coils have been made and sent to several leading electricians at home and abroad. The form of bobbin adopted for putting up the wire, and shown in Plate X. fig. 1, has been found very convenient, as it can be immersed in water during an observation. The wire is twice coated with silk, and protected by being imbedded in solid paraffin.

Besides the coils already mentioned, ten unit-coils have been made, which will be deposited at the Kew Observatory.

Any one possessing a copy of the B.A. unit may have it compared at any future time against one of these coils for a small payment.

Of the coils to be sent to Kew, two are of the platinum-silver alloy, two of the gold-silver alloy, two of a platinum-iridium alloy, and two of commercially pure platinum. Two mercury units have also been prepared.

With so many coils for reference, made of such different metals, it appears quite improbable that the unit now proposed should be lost.

Along with the above-mentioned coils will be preserved the standard coil used in the experiments first referred to, the coil used in the similar experiments made by your Committee in 1863, and several copies of these coils.

Of the coil called "June 4th" in the Report of your Committee for 1863, two German-silver copies have been made. Of the other coil used in 1864, two German-silver, two gold-silver, and one platinum-silver copy have been made.

These coils have twice been recompared together at intervals of three months, and will be again compared, and if they are still found not to have altered, will be deposited at the Kew Observatory for reference, their values being engraved on them.

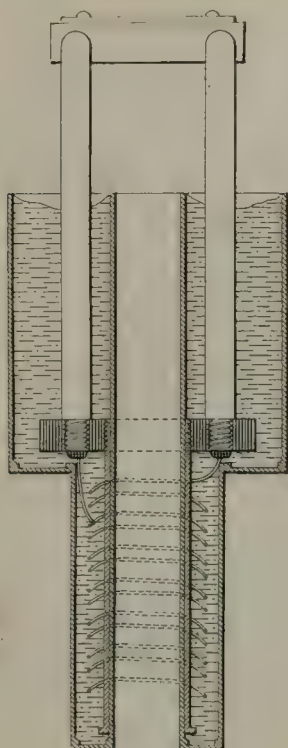
The method adopted to obtain the unit from the standard which had at a certain temperature a resistance of 4.6677 B.A. units was this:—

Coils were made with the following approximate resistances, viz.:

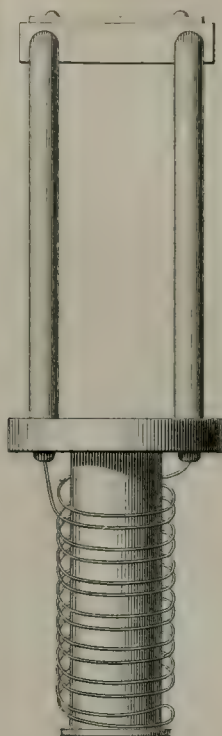
| | | | | |
|--|--------|------------------|-----|--------------------|
| Two coils nearly equal to one-half a unit, | called | $\frac{1}{2}(a)$ | and | $\frac{1}{2}(b)$. |
| " | " | one unit | " | 1 (a) " 1 (b). |
| One coil | ;; | two units | " | 2 |
| " | ;; | two and a half | " | $2\frac{1}{2}$ |

* Messrs. Johnson and Matthey inform us that this alloy has been in use for nearly twenty years.

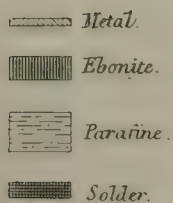
Standard Unit of Electrical Resistance.



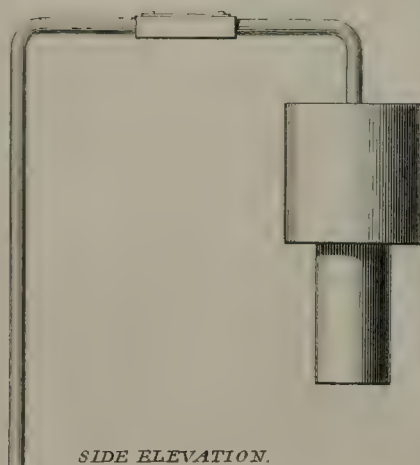
SECTION.



ELEVATION.



$\frac{1}{2}$ full size.



SIDE ELEVATION.



PLAN.

$\frac{1}{4}$ full size.

Engraved by J.W. Lowry.



The electrical balance used was that described in a paper on the reproduction of a unit by chemical means in the Report of your Committee for 1864.

With this instrument, two conductors, differing in resistance by not more than 3 per cent., could be directly compared, and the ratio found depended on to 0·0025 per cent.

Numerous comparisons were made by means of this balance between the following sets of coils, viz. :—

| | | |
|-----------------------------------|-------------------|--------------------|
| $\frac{1}{2}(a)$ | was compared with | $\frac{1}{2}(b)$. |
| $\frac{1}{2}(a) + \frac{1}{2}(b)$ | „ | 1 (a). |
| 1 (a) | „ | 1 (b). |
| 1 (a) + 1 (b) | „ | 2 |
| $2 + \frac{1}{2}(a)$ | „ | $2\frac{1}{2}$ |
| $2 + 2\frac{1}{2}$ | „ | standard. |

By taking the mean of several very concordant observations, the value of the coil 1a was found in terms of the standard, and therefore of the unit, to a great degree of accuracy, and from this coil the first platinum-silver unit was constructed.

All the coils to be issued are recompared some weeks after they are made, and rejected if they are found to have altered in resistance by 0·01 per cent.

All the coils sent out are correct at the temperature written on them to within 0·01 per cent., and this temperature lies between 14·5 and 16·5 in all cases.

Report of the Committee, consisting of Major-General SABINE, P.R.S., Sir JOHN HERSCHEL, Bart., F.R.S., J. P. GASSIOT, F.R.S., and Sir R. I. MURCHISON, Bart., F.R.S., appointed for the purpose of communicating to the Russian Government the opinion of the British Association, that the establishment of magnetical observations on the Kew system at the Observatory of Tiflis, by Professor Moritz of that place, would largely conduce to the furtherance of Magnetical Science. By General SABINE, P.R.S.

At the Meeting of the British Association at Bath in 1864, a resolution was passed by the General Committee appointing a committee, of which my name stood first on the list of its members, “for the purpose of communicating to the Russian Government the opinion of the British Association, that the establishment of magnetical observations on the Kew system at the Observatory of Tiflis, by Professor Moritz of that place, would largely conduce to the furtherance of magnetical science.”

Not having been myself present at the Bath Meeting, and knowing nothing of what had passed there, beyond the words of the resolution transmitted to me by the Assistant-Secretary, Mr. Griffith, I addressed the letter marked No. 1 to Mr. Hopkins, the General Secretary.

No. 1.

“13 Ashley Place, Nov. 9, 1864.

“MY DEAR SIR,—I received a few days since from Mr. Griffith a notice of a resolution adopted by the General Committee of the British Association at

Bath, appointing a committee, my own name standing as the first member, 'for the purpose of communicating to the Russian Government the opinion of the British Association, that the establishment of magnetical observations on the Kew system at the Observatory of Tiflis, by Professor Moritz of that place, would largely conduce to the furtherance of magnetical science.'

"A communication to a foreign Government is a serious and somewhat delicate matter. The communication must necessarily pass, I believe, either through our own Government, or through the Russian Ambassador in London; and must in either case, I apprehend, be made by the President of the Association. The duty of the Committee is therefore to supply the President with such information, if they can obtain it themselves, as may enable him to fulfil in the best manner the wishes of the General Committee.

"Not having been present myself at the Bath Meeting, I have no knowledge of the discussion, either at the Section which originated the resolution, or in the Committee of Recommendation which adopted and recommended it, which doubtless preceded and influenced its adoption. I wish, therefore, to seek through you for information on some points on which more knowledge than I possess is desirable.

"Professor Moritz is, I believe, and has been for some years past, Director of an Observatory at Tiflis, which is one of several observatories established in different parts of the Russian empire, acting under and in concert with the 'Observatoire Central Physique de la Russie' at St. Petersburg, receiving instruments and instructions from the Central Observatory, reporting to and transmitting their observations in MSS. to M. Kupffer, the Director-General of the Magnetical and Meteorological Observatories in Russia, by whom the whole of the observations so transmitted are published annually in the well-known work '*Annales*,' &c., according to a uniform pattern. The purpose of the resolution, if I understand it correctly, is, that the instruments and system of observation hitherto pursued at Tiflis should be changed by the addition of magnetical instruments on the pattern of those at Kew, comprehending the tabulation from the photograms, the reduction of the observations, and their application to theoretical conclusions. Of course I do not entertain the slightest doubt of the advantage that might be expected to result to magnetical science if the recommendation were acceded to and perseveringly and faithfully carried out; but in respect to the probability of its being received with favour by the Russian Government, and acceded to, it is material to inquire whether Professor Moritz's application for the interference of the British Association on behalf of the Tiflis Observatory was made with the knowledge and concurrence of the head of the department under which he acts. It is unnecessary to dwell on the very different aspect which the whole matter would assume according as the reply to this question be in the affirmative or in the negative.

"The University of *Kasan*, a station of peculiar magnetical importance in theoretical respects, but which is *not* one of the stations of the Russian system, being desirous of forming such an establishment, sent its professor of mathematics, Professor Bolzani, to England in 1862 to examine and report on the magnetical instruments employed in England. Professor Bolzani strongly recommended the adoption of instruments similar to those at Kew, with which, and the modes of reduction of the results and their theoretical applications, he made himself fully conversant by attendance at Kew. Whereupon the University addressed a Memorial to the Russian Government, offering, on being supplied with instruments similar to those at Kew, to be at the whole expense themselves of the locale, the staff for observation and for reduction,

and of publication. The reply was, not a refusal, but a postponement of the consideration of the Memorial until the Russian finances should have recovered from the heavy expenditure of the Crimean war. How far this decision was influenced by the spirit of centralization, which is very strong in Russia, and causes all such applications to be referred in the first instance for a report from the central head, cannot of course be known; but it is worthy of remark that it was immediately followed by an application from M. Kupffer for a complete set of instruments similar to those at Kew for the Central Observatory at St. Petersburg. These have been furnished, and I have very recently learnt from M. Kupffer that they have arrived, and have been established in the Observatory. The observations have not yet commenced, because the gas-pipes leading to the observatory are not yet quite finished. My impression is, though I can only speak of it as an *impression*, that M. Kupffer purposes to make himself thoroughly acquainted with the instruments by using them under his own eye; and if he approves of them, to have others made like them at St. Petersburg (or to procure them from England as he may deem best) for those observatories under his direction to which they may appear most suitable, and for which the Government is willing to supply the necessary funds. It may be hoped that the observations at such observatories will be reduced and applied to theoretical deductions, which has not been the case hitherto in the Russian observatories. The publication of the crude observations is comparatively of little value; but the labour of the reduction adds very considerably to the cost.

“And this brings me to a second inquiry, which may be very important in contributing to the success or otherwise of the recommendation contemplated by the resolution adopted by the General Committee. Was it understood from Professor Moritz that there existed at Tiflis a separate fund by which, if the instruments were supplied by the Russian Government, the current cost of the locale, the staff for observation and reduction, and for publication, might be defrayed? This was the proposition from Kasan; and if made on behalf of Tiflis, might entitle Tiflis to be placed in the same category of independence of the Central authority.

“The object sought by the resolution of the General Committee is clearly defined—the establishment of magnetical observations on the Kew system at the Observatory of Tiflis by *Professor Moritz*. It is a perplexing circumstance, however, that I received from Professor Moritz a letter dated the 27th of September, viz. a few days *after* the Bath Meeting, desiring an interview to discuss his project, ‘d’un levé magnétique, qu’on se propose d’exécuter au Caucase.’ His letter neither names or refers in any way to ‘magnetical observations on the Kew system at Tiflis.’ The two projects are incompatible if they are to be conducted by the same person. Is it possible that there may have been some misunderstanding between the Professor and the gentlemen who brought forward the Resolution, as to which project is uppermost in the Professor’s mind? A ‘Lévé magnétique’ in the Caucasus is a far less costly affair than such an observatory as is contemplated at Tiflis. There would be a degree of awkwardness if Professor Moritz’s desire to be employed in a magnetic survey of the Caucasus were brought before the Russian Government at the same time with the recommendation of the British Association that he should be employed in a work which would require his whole time and thoughts at Tiflis for some years to come. It is a point which I should think Sir Charles Lyell would desire to be cleared up before he should make his communication to the Russian Government. The President of the Section which originated the proposition, or the officers of the Association who were

present at the discussions in the Committee of Recommendations, may be able to throw some light on which of the two projects M. Moritz is himself most desirous of pressing. I may at the same time remark that the Committee appointed to aid in the observatory project can take no official cognizance of the survey in the Caucasus.

“My object in addressing this letter to you is to obtain either from yourself, or through your intermediation from other Officers of the Association, or from the President of the Section by whom the recommendation was brought forward, any information which they can furnish which may be useful to Sir C. Lyell in the communication he will have to make with the Russian Government. It is important to keep in view that, whilst we desire to give every proper aid to Professor Moritz’s wishes, we should have at the same time a clear understanding of the recommendation we are making in all the lights in which it may be viewed. Will you therefore kindly return me this letter, after you have communicated its contents to any person who you think may throw light on any of the points touched upon, and accompanied by any documents referring to the recommendation which may be in the hands of the officers, or which they may be able to procure? I will then communicate with the other members of the Committee.

“Sincerely yours,

“William Hopkins, Esq.,

“EDWARD SABINE.”

General Secretary of the British Association.”

At the time when my letter reached Mr. Hopkins he was already suffering from the illness which has since obliged him (to the general regret) to resign the Secretaryship. My letter was, however, immediately sent to Mr. Galton, associated with Mr. Hopkins in the duties of the Secretary’s office, who most readily and promptly undertook to communicate with Professor Moritz himself, who had returned to the continent; and also to make my letter known to Sir Charles Lyell, the President of the Association, by whom any direct application, either to the Russian Government or to our own, should such an application to either Government be deemed expedient, would have to be made.

Mr. Galton’s letter to myself, of Feb. 27 (marked No. 2), states the result of his communication with Professor Moritz, and was as follows:—

No. 2.

“42 Rutland Gate, W., Feb. 27, 1865.

“MY DEAR GENERAL,—I have at length received a letter from Professor Moritz, dated Feb. 5 (? old style), which I enclose. It is not satisfactory, for it does not reply to all my questions; nevertheless you may possibly find it sufficient to afford a basis to some limited action.

“1. Professor Kupffer is stated to approve of Professor Moritz’s scheme, and of the resolution of the British Association.

“2. The funds to carry the scheme into effect would be supplied, if at all, by the Russian (? Imperial) Government, through the Grand Duke Michael, Lieut. of the Emperor in the Caucasus. His decision is final, and to him the resolution of the British Association would be most properly addressed.

“3. Professor Moritz wishes to obtain a self-registering apparatus of the Kew pattern, partly to afford comparative observations with those he proposes to make (by means of portable instruments) at the chief geodetical stations of the Caucasus survey. He also wants the self-registering instruments for regular work at Tiflis, where he deplors the insufficiency of assistants capable of making two hourly observations.

"4. He does not say whence he proposes to obtain the above mentioned portable instruments, nor does he say anything concerning the tabulation of the photograms of the self-registering instruments; nor of the reduction of the observations, nor of their application to theoretical conclusions. Neither does Professor Moritz give cause to believe that he has had, as yet, the necessary experience to enable him to establish a regular magnetical observatory. (I pointedly made inquiries of him on this very subject in my second letter, dated Feb. 3.)

"The final paragraph of Professor Moritz's letter is his own version of what took place at the Bath Meeting, and for that he is alone responsible. It apparently has formed part of some report he has made to the Grand Duke, who commissioned him to attend the Meeting.

"I herewith return your letter of Nov. 9, addressed to the General Secretary. It has formed the basis of both my letters to Professor Moritz.

"Yours very faithfully,

"Major-General Sabine, R.A."

"FRANCIS GALTON."

On the receipt of Mr. Galton's letter of Feb. 7 I wrote to M. Kupffer, then at St. Petersburg, referring to the resolution passed at Bath, and to Professor Moritz's communication with Mr. Galton, and expressing a desire to be guided by his advice in any further step which it might be advisable to take.

It had been previously arranged between M. Kupffer and myself that he should be in London in April or May of this year, for the purpose of discussing many questions bearing on magnetical and meteorological observations. In reply to my letter he referred to his proposed visit to London as a suitable time to discuss fully the subject of Professor Moritz's wishes, at which discussion it was my intention to have asked Mr. Galton and the members of the Committee joined with myself in the resolution of the General Committee to be present. But in May I received the intelligence of M. Kupffer's unexpected death, and I have not yet learnt who has been, or is to be; appointed his successor.

EDWARD SABINE.

September 1, 1865.

Appendix to Report of the Committee on the Distribution of the Vertebrate Remains from the North Staffordshire Coal Field. By JOHN YOUNG, M.D., F.R.S. Edinb.

IN the large series of specimens obtained by Mr. Molyneux, the genus *Paleoniscus* is numerically the most important. The vast majority of the specimens are referable to two species, *P. ornatissimus* and *P. Egertoni*. The variations in the proportions of the body and sculpture of the scales admit of a series being established so gradual that at no point can a sharp distinction be drawn between the two species. The occurrence on individuals in this series, of scales identical with those of *P. monensis*, renders it probable that the last-named species, founded on isolated scales from Anglesea, is only a variety of the North Staffordshire forms, the difference in conjectured bulk being perhaps due to local conditions. A small number of specimens belong to *P. striolatus* or *P. Robisoni*. The comparison of these specimens, and others elsewhere, with the types in the Royal Society's collection at Edinburgh, raise doubts in the writer's mind as to the distinctness of the two species. In

these, as in the foregoing species, the comparison of many individuals from beds of the same general age occurring in the same district, illustrates the wide range of variation which accompanies great fertility. Similarly, the many specimens of the Mansfeldt species in the Royal College of Surgeons, in the British Museum, in Sir P. Egerton's Cabinet, and in Edinburgh, confirm the hesitation with which Geinitz enumerates them, and justify the reduction of their specific differences within very narrow limits. The figures of the same species given by him, by Agassiz, and by King, differ in general proportions and the position of the fins, as markedly as do the Burdie House forms, and in this respect fairly parallel the variations in the more limited area of North Staffordshire. The comparison of individuals belonging to prolific living species, as the Herring, Salmon, Trout, yields similar results. The writer drew attention to the American specimens in the Geological Society's collection. The species representing those of the English Carboniferous series are associated with forms allied to those of Mansfeldt, whose coexistence in Staffordshire has been asserted, but is not yet certain.

Of the genus *Rhizodopsis*, established provisionally by Prof. Huxley for the reception of certain specimens whose cranial and dental characters approached those of *Rhizodus*, Ow., while the scales, not yet found in unquestionable relation to the crania on which the older genus was founded, belong to the cycloidal section of the Glyptodipterini, several good examples occur. None of the individuals reach the size of *Rhizodus*, with which they are coextensive in distribution in the English and Scottish Coal-fields. The facial bones are not determinable. The strong conical teeth with plicate bases are of two sizes; the larger, slightly incurved at the apex, want the lateral compression which marks the lanianaries of *Rhizodus*. Only two pairs of jugular plates seem to have existed. The pectoral fins are lobate; the two dorsals, the ventral and anal, opposite each other respectively, are placed in the posterior half of the body. The vertebral rings are thin, shallow. The scales are cordate, but vary in the proportions of their measurements at different parts of the body. Their ornament consists of concentric and radiating ridges, the former entire on the sides, but interrupted at either extremity by the latter; the concentric ridges of the free area are robust. A subcentral boss on the lower surface, nearer the anterior margin, corresponds to the point of radiation on the upper aspect. The amount of overlap is uniform, extending to one-third of the surface. These are the chief points in which this genus differs from other Glyptodipterines. The character of the larger teeth justifies its retention as distinct from *Rhizodus*. Reliable specific differences are wanting; the greater flexibility of the scales in specimens from shale than in those from the ironstones, is due perhaps as much to the nature of the matrix as to different stages of growth; while greater and smaller size are not accompanied by other noticeable variations.

Certain cycloidal scales were determined by Prof. Huxley in 1863 to belong to a new genus which he named *Cycloptychius*. His description of the genus was not then published, though read at the British Association. Several excellent examples have since been found; their structure is in abstract as follows.

Body: average length 5 inches, slender, tapering to a finely pointed caudal extremity; covered with thin scales, cycloid anteriorly, pointed posteriorly, marked with well-defined concentric ridges. *Head* nearly one-fifth of length of body, compressed; muzzle rounded. Orbits far forward, bounded by large supraorbitals, prefrontals, and inferiorly by a long suborbital bar. Præmaxilla large, its anterior margin prolonged laterally. Maxilla in one piece,

curved slightly upwards anteriorly, posteriorly descending more abruptly. Mandible in one piece, tapering to a slender, slightly upcurved, symphysial extremity. Both jaws beset with fine conical smooth teeth of two sizes, the larger about three times that of the smaller, among which they are set at regular intervals, and from which they are distinguished only by size. Operculars narrow, elongate; suboperculars small, square. No trace of inter-operculars. Branchiostegal rays numerous, flattened, enamelled. The sculpture of the cranial and facial bones consists of close-set tubercles, sometimes confluent into short ridges. The occipital bones are perhaps represented by large scale-like plates occurring close to the head. *Pectoral arch* weak; scapulars flat, articulated, not coalescent with the truncated coracoids. *Pectoral fins* small, not lobate. *Ventrals* small, at middle of body. *Dorsal* and *anal* small, triangular, equal, opposite; intermediate between ventrals and caudal. *Tail* markedly heterocercal; upper lobe slender; its short rays entirely beneath the prolonged axis of the body. The rays of the lower lobe increase in length up to the fifth or sixth, which exceed the anal fin; and thence diminish till they meet those of upper lobe at an angle of 35° . The dorsal fin is preceded by a few, the upper caudal lobe is covered by many fulcral scales. The thin enamelled *scales*, disposed in oblique series, are similar over the body, those of the upper and lower margin being slightly smaller than those on flanks. The obliquity of their axis from the production of the posterior inferior angle, gives them *in situ* a rhomboidal appearance. The ridges are more numerous on the lower than the upper half, and are not continuous across.

This very elegant genus is nearly allied to *Palæoniscus* and *Catopterus*, Renf., and ranks therefore with them among the *Lepidosteidae*. It has as yet been found only in Staffordshire. Species unica *Cycloptychius carbonarius*, Huxley.

Specimens of a tooth, named *Strepsodus*, in the Jermyn Street Collection and Catalogue, are frequent. This tooth, figured as *Holoptychius sauroides* in the Tyneside Natural History Club's Reports, has also been referred to *Megalichthys*, but is generically distinct. It varies from three-eighths to one inch in length, and is distinguished by its bayonet form, a knee-bend occurring at the commencement of its distal fourth; it is slightly curved backwards, the convex surface being smooth, the concave traversed by fine parallel, longitudinal, discontinuous ridges, which die out as they curve outwards towards the anterior aspect. The pulp occupies three-fourths of the base, but is reduced to a point near the knee-bend. Seven such teeth are preserved, with a fragment of a jaw, in Mr. Ward's Cabinet at Longton: the implanted equals the exerted portion in length. On the same slab a scale with radial furrows occurs. Teeth of the same kind are associated on a block of shale in the Hunterian Museum, Glasgow, with cycloidal scales, whose free surface is traversed by radiating broad grooves, large vertebral rings whose central space is one-third to one-fifth of the whole diameter, flattened neural spines and rounded bony spicula, which are probably fin-rays. The form and sculpture of this tooth are amphibian rather than piscine; while neither order offers any good analogy to its mode of occurrence in the jaw above mentioned. Several doubtful fragments and a deep amphicœlous vertebra suggest the presence of Amphibia in the Longton district.

A quadrilateral scale, with rounded angles, provisionally named *Rhomboptychius*, Huxl., is found near Longton; one specimen measures two square inches, but is exceptionally large. The posterior smaller portion, marked off by two oblique shallow grooves, is ornamented with coarse concentric ridges;

the anterior with very fine striæ crossed at the margins by equally fine radii. The fine pores between, but not on the coarse ridges, are wanted on the anterior surface. The scale seems to belong to some large Glyptodipterine, and merits description from its occurrence in the same shales with the tooth last described.

The large transversely oval scale, named *Dendroptychius*, belongs to the same group; its anterior half is finely tubercular by the intersection of concentric and radial striæ; the distant, rudely parallel, vermicular, frequently bifurcated ridges of the posterior do not radiate from a centre, but pass from the whole transverse diameter. The determination of this, like the preceding from the same locality, awaits further discoveries.

The Acanthodian remains are abundant and well preserved.

Scales of two species of *Gyrolepis* occur along with those of *Palæoniscus*. *Amblypterus* is represented by a few scales.

The Plagiostomous remains are numerous and varied; among them occur *Orodus*, *Helodus*, *Cladodus*, and *Otenodus*. Among them, as among the numerous spines, are several forms which are yet under investigation.

Of the genus *Platysomus*, one species, *P. parvulus*, and a variety unnamed, are found; the scale ornament of the one is tubercular*, of the other striated. *P. striatus*, obtained in Derbyshire, is wanting in this coal-field.

The list both of genera and species will doubtless be augmented when the large mass of materials, collected by Mr. Molyneux and others, shall have been more fully investigated.

First Report on the Structure and Classification of the Fossil Crustacea. By HENRY WOODWARD, F.G.S.

A GRANT having been made in September last at Bath (1864) in aid of my researches into the structure and classification of the Fossil Crustacea, for which the Earl of Enniskillen, Professor Phillips, and Mr. C. Spence Bate were appointed a Committee, I beg to submit my first Report.

The first portion of my investigation relates to the Crustacea of the Devonian and Upper Silurian formations belonging to the order *Eurypterida*.

These are now elaborated, and will be published in a Monograph, with plates and woodcuts of all the species, by the Palæontographical Society during the ensuing year.

The following is an abridged list of the genera:—

| | |
|-------------------------|---------------------|
| 1. Eurypterus | 9 species examined. |
| 2. Pterygotus | 10 " " |
| 3. Slimonia | 3 " " |
| 4. Stylonurus | 6 " " |
| 5. Hemiaspis | 5? 1 " |

and includes three genera defined, viz.:—

Slimonia†, *Stylonurus*‡, and *Hemiaspis*§; and also six new species added

* A new genus, *Amphicentrum*, has been founded by the writer upon certain fossils bearing certain strong anatomical resemblances to *Platysomus*, while the dentition indicates affinities with the Pycnodonts. The description of this genus, with a review of its relations, will shortly appear elsewhere.

† See Intellectual Observer, vol. iv. 1863, p. 229, "On the Seraphim and its Allies."

‡ See Geological Magazine, vol. i. 1864, p. 196, "New Palæozoic Crustacea."

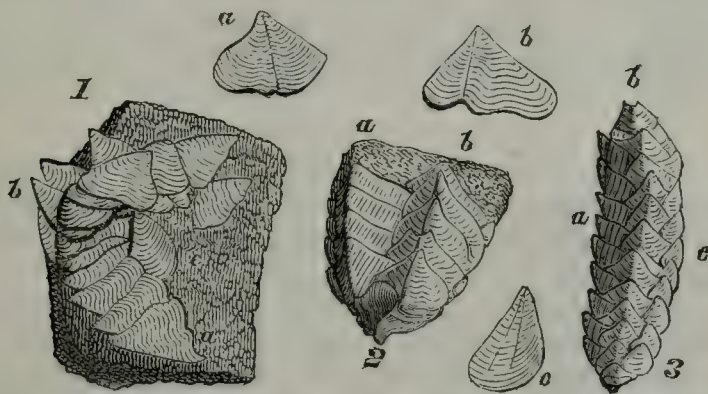
§ See Quart. Journ. Geol. Soc. vol. xxi. pt. 4, Nov. 1865, "On *Hemiaspis*."

to the list, including the great *Stylonurus Scoticus**, nearly 4 feet in length.

Of the other species we now possess much more ample material than was at the disposal of Messrs. Huxley and Salter in 1859, when their Monograph appeared, and many important details in the structure and position of the parts and their mutual relations are now elaborated.

In addition to the Devonian localities of Herefordshire, Forfar, Arbroath, and Dundee, the Upper Silurian of Lanark, and the Lower Ludlow of Leintwardine, Shropshire, all of which have yielded new and characteristic forms (several of them described by me during the past year), I have lately obtained from the Wenlock Limestone and Shale, Dudley, good evidence that in this locality also species of *Pterygotus* occur.

Until June 1865, the oldest known Cirripede was the *Pollicipes Rhæticus* from the Rhætic beds of Somersetshire; but I have just described† a new Cirripede with intersecting rows of plates (similar to the Cretaceous genus *Loricula*), from the Wenlock Limestone and shale of Dudley, figures of which are added‡.



TURRILEPAS WRIGHTII, H. Woodw. (*Chiton Wrightii*, De Kon.).

Fig. 1. Specimen from Mr. E. J. Hollier's collection.

Fig. 2. " Mr. Charles Ketley's "

Fig. 3. " Mr. H. Johnson's "

Figs. *a*, *b*, *c* represent the three forms of plates of which the several rows are composed in figs. 1-3, which bear the corresponding letters. The opercular valves are not known.

Another Cirripede of the genus *Pyrgoma*, occurring recent on the south coast of England and Ireland, living in deep water attached to the edge of the cup of *Caryophyllia*, and fossil in the Coralline Crag of Suffolk, has now been detected by me in the Upper Chalk of Norwich. As this is a new species I have named it *Pyrgoma cretacea*. It is interesting to find it associated with the same genus of corals (*Caryophyllia*) both in the Chalk and in recent seas.

I have examined and determined six genera, and am preparing descriptions of about sixteen new species of Liassic Crustacea.

* See Quart. Journ. Geol. Soc. vol. xxi. pt. 4, Nov. 1865, "On *Hemiaspis*."

† See Quart. Journ. Geol. Soc. vol. xxi. pt. 4.

‡ Two detached valves of this fossil were discovered by Mr. John Gray of Hagley, and described as a *Chiton* by M. De Koninck, Bulletins de l'Acad. de Bruxelles, 1857, 2nd series, vol. iii. p. 199, pl. 1, f. 2.

Among the new genera are—

| | |
|------------------------|-----------|
| 1. Palinurina | 2 species |
| 2. Aeger | 3 „ |
| 3. Glyphæa | 2 „ |
| 4. Pseudoglyphæa | 2 „ |
| 5. Scapheus | 1 „ |

besides the genus *Eryon*, to which two or three new species have to be added.

I have likewise detected a minute species of *Squilla*. All these seven genera (save one) characterize also the Solenhofen limestone of Bavaria* (Upper White Jura).

I have now to notice a remarkable burrowing Crustacean of the family *Thalassinæ* (a genus of which (*Callinassa*) occurs in the uppermost bed of the Cretaceous series at Maestricht), as occurring in our Hempstead series (Upper Eocene) in the Isle of Wight, and another species in the Greensand formation of Colin Glen, Belfast.

The death of my brother and colleague Dr. Samuel P. Woodward (my best scientific adviser during the past eight years), has materially retarded my accustomed work; I beg therefore to be allowed to speak of this as my first report only, and that I may be permitted next year to offer a more complete and detailed statement of my researches in this interesting group.

Report on the Theory of Numbers.—Part VI. By H. J. STEPHEN SMITH, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.

124. *Application of the Theory of Elliptic Functions to Quadratic Forms.*—*The Theta Functions of Jacobi.*—It will be for the convenience of the reader to give in this place a brief statement of a few principles and results which belong to the theory of elliptic functions, and to which we shall have occasion to refer in the following articles.

The Theta functions of Jacobi are defined by the equation

$$\theta_{\mu, \nu}(x, \omega) = \sum_{m=-\infty}^{m=+\infty} (-1)^{m\nu} \varepsilon^{in} \left[(2m+\mu) \frac{x}{a} + \frac{1}{4} (2m+\mu)^2 \omega \right],$$

or if $\varepsilon^{i\pi\omega} = q$, by the equation

$$\theta_{\mu, \nu}(x, \omega) = \sum_{m=-\infty}^{m=\infty} (-1)^{m\nu} q^{\frac{1}{4} (2m+\mu)^2} \varepsilon^{(2m+\mu) \frac{i\pi x}{a}}.$$

In these equations, μ and ν are given integral numbers; ω is an imaginary constant, having for the coefficient of i in its imaginary part a quantity different from zero and positive; so that the analytical modulus of q is inferior to unity, and the series defining the Theta functions is convergent for all values of x real or imaginary; lastly, a is a constant at present undetermined, but to which we shall hereafter assign a particular value depending on that of ω . When it is not necessary to specify the value of ω , we shall write $\theta_{\mu, \nu}(x)$, instead of $\theta_{\mu, \nu}(x, \omega)$. The following equations are immediate consequences of the definition of the Theta functions:

* See Oppel's Palaeontolog. Mittheilung. Munich, 1863.

$$\theta_{\mu+2, \nu}(x) = (-1)^\nu \theta_{\mu, \nu}(x). \quad (1)$$

$$\theta_{\mu, \nu+2}(x) = \theta_{\mu, \nu}(x). \quad (2)$$

$$\theta_{\mu, \nu}(-x) = (-1)^{\mu\nu} \theta_{\mu, \nu}(x). \quad (3)$$

$$\theta_{\mu, \nu}(x+\alpha) = (-1)^\mu \theta_{\mu, \nu}(x). \quad (4)$$

$$\theta_{\mu, \nu}(x+a\omega) = (-1)^\nu \theta_{\mu, \nu}(x) \varepsilon^{-i\pi\left(2\frac{x}{a}+\omega\right)}. \quad (5)$$

$$\theta_{\mu+\mu', \nu+\nu'}(x) = \theta_{\mu, \nu}\left(x+\frac{1}{2}(\mu'\omega+\nu')\alpha\right) \times \varepsilon^{\pi i\left[\mu'\frac{x}{a}+\mu'^2\frac{\omega}{4}-\frac{\mu\nu'}{2}\right]}. \quad (6)$$

Thus there are only four different Theta functions, $\theta_{0,0}(x)$, $\theta_{0,1}(x)$, $\theta_{1,0}(x)$, $\theta_{1,1}(x)$ (equations 1 and 2); of these, the first three are even functions, the last an uneven function (equation 3); they are all periodic, having a or $2a$ for their period, according as μ is even or uneven (equation 4); the quotient $\frac{\theta_{\mu, \nu}(x)}{\theta_{\mu', \nu'}(x)}$ is doubly periodic, having $a\omega$ or $2a\omega$ for its second period, according as $\nu-\nu'$ is even or uneven (equation 5); finally, any one of the four can be expressed as the product of any other by an exponential factor (equation 6).

The identical equations

$$\left. \begin{aligned} &1+q(v+v^{-1})+q^4(v^2+v^{-2})+q^9(v^3+v^{-3})+q^{16}(v^4+v^{-4})+\dots \\ &=(1-q^2)(1-q^4)(1-q^6)\times\dots\times(1+qv)(1+q^3v)(1+q^5v)\dots \\ &\quad \times(1+qv^{-1})(1+q^3v^{-1})(1+q^5v^{-1})\dots \end{aligned} \right\} \quad (7)$$

$$\left. \begin{aligned} &q^{\frac{1}{4}}(v+v^{-1})+q^{\frac{9}{4}}(v^3+v^{-3})+q^{\frac{25}{4}}(v^5+v^{-5})+\dots \\ &=(1-q^2)(1-q^4)(1-q^6)\dots\times q^{\frac{1}{4}}(v+v^{-1}) \\ &\quad \times(1+q^2v^2)(1+q^4v^2)(1+q^6v^2)\dots \\ &\quad \times(1+q^2v^{-2})(1+q^4v^{-2})(1+q^6v^{-2})\dots, \end{aligned} \right\} \quad (8)$$

in which v is any quantity whatever, and q any quantity of which the analytical modulus is inferior to unity, express an important property of the Theta functions. Elementary demonstrations of the first have been given by Jacobi and Cauchy*; the second is immediately deducible from it, by writing qv^2 for v , and multiplying by $q^{\frac{1}{4}}v$. We infer from these identities the four formulæ

$$\begin{aligned} \theta_{0,0}(x) &= \sum_{m=-\infty}^{+\infty} q^{m^2} \cos \frac{2m\pi x}{a} \\ &= \prod_{m=1}^{\infty} (1-q^{2m}) \prod_{m=1}^{\infty} \left(1+2q^{2m-1} \cos \frac{2\pi x}{a} + q^{4m-2}\right); \quad (9) \end{aligned}$$

$$\begin{aligned} \theta_{0,1}(x) &= \sum_{m=-\infty}^{+\infty} (-1)^m q^{m^2} \cos \frac{2m\pi x}{a} \\ &= \prod_{m=1}^{\infty} (1-q^{2m}) \prod_{m=1}^{\infty} \left(1-2q^{2m-1} \cos \frac{2\pi x}{a} + q^{4m-2}\right); \quad (10) \end{aligned}$$

* Jacobi, *Fundamenta Nova*, p. 176-183; Crelle's *Journal*, vol. xxxvi. p. 75; Cauchy, *Comptes Rendus*, vol. xvii. p. 523, 567. See also the note (by M. Hermite), 'Sur la Théorie des Fonctions Elliptiques' in the 6th edition (Paris, 1862) of Lacroix, *Traité Élémentaire du Calcul Différentiel*, vol. ii. p. 397.

$$\begin{aligned}\theta_{1,0}(x) &= \sum_{m=-\infty}^{+\infty} q^{\frac{1}{4}(2m+1)^2} \cos(2m+1) \frac{\pi x}{a} \\ &= 2q^{\frac{1}{4}} \cos \frac{\pi x}{a} \prod_m (1-q^{2m}) \cos \prod_m \left(1+2q^{2m} \frac{2\pi x}{a} + q^{4m}\right); \quad (11)\end{aligned}$$

$$\begin{aligned}\frac{1}{i} \theta_{1,1}(x) &= \sum_{m=-\infty}^{+\infty} (-1)^m q^{\frac{1}{4}(2m+1)^2} \sin(2m+1) \frac{\pi x}{a} \\ &= 2q^{\frac{1}{4}} \sin \frac{\pi x}{a} \prod_m (1-q^{2m}) \prod_m \left(1-2q^{2m} \cos \frac{2\pi x}{a} + q^{4m}\right); \quad (12)\end{aligned}$$

by which the Theta functions are expressed as convergent products of an infinite number of factors.

Other important consequences are deducible from the equation

$$\left. \begin{aligned} & 2\theta_{\mu_1, \nu_1}(x_1) \theta_{\mu_2, \nu_2}(x_2) \theta_{\mu_3, \nu_3}(x_3) \theta_{\mu_4, \nu_4}(x_4) \\ &= \theta_{\sigma-\mu_1, \sigma'-\nu_1}(s-x_1) \times \theta_{\sigma-\mu_2, \sigma'-\nu_2}(s-x_2) \times \theta_{\sigma-\mu_3, \sigma'-\nu_3}(s-x_3) \\ & \quad \times \theta_{\sigma-\mu_4, \sigma'-\nu_4}(s-x_4) \\ &+ \theta_{\sigma-\mu_1, \sigma'-\nu_1+1}(s-x_1) \times \theta_{\sigma-\mu_2, \sigma'-\nu_2+1}(s-x_2) \times \theta_{\sigma-\mu_3, \sigma'-\nu_3+1}(s-x_3) \\ & \quad \times \theta_{\sigma-\mu_4, \sigma'-\nu_4+1}(s-x_4) \\ &+ (-1)^{\sigma'} \theta_{\sigma-\mu_1+1, \sigma'-\nu_1}(s-x_1) \times \theta_{\sigma-\mu_2+1, \sigma'-\nu_2}(s-x_2) \\ & \quad \times \theta_{\sigma-\mu_3+1, \sigma'-\nu_3}(s-x_3) \times \theta_{\sigma-\mu_4+1, \sigma'-\nu_4}(s-x_4) \\ &+ (-1)^{1+\sigma'} \theta_{\sigma-\mu_1+1, \sigma'-\nu_1+1}(s-x_1) \times \theta_{\sigma-\mu_2+1, \sigma'-\nu_2+1}(s-x_2) \\ & \quad \times \theta_{\sigma-\mu_3+1, \sigma'-\nu_3+1}(s-x_3) \times \theta_{\sigma-\mu_4+1, \sigma'-\nu_4+1}(s-x_4), \end{aligned} \right\} \quad (13)$$

which contains four independent arguments, x_1, x_2, x_3, x_4 , and in which $2s = x_1 + x_2 + x_3 + x_4$, $2\sigma = \mu_1 + \mu_2 + \mu_3 + \mu_4$, $2\sigma' = \nu_1 + \nu_2 + \nu_3 + \nu_4$; the numbers $\mu_1, \mu_2, \mu_3, \mu_4$ and $\nu_1, \nu_2, \nu_3, \nu_4$ being subject to the restriction that their sums are respectively even, so that σ and σ' are integral*. Let $\sqrt{\kappa}$, $\sqrt{\kappa'}$ be two quantities defined by the equations

$$\sqrt{\kappa} = \frac{\theta_{1,0}(0)}{\theta_{0,0}(0)}; \quad \sqrt{\kappa'} = \frac{\theta_{0,1}(0)}{\theta_{0,0}(0)}; \quad \dots \dots \dots (14)$$

attributing in (13) to the elements

$$\begin{vmatrix} x_1, & x_2, & x_3, & x_4 \\ \mu_1, & \mu_2, & \mu_3, & \mu_4 \\ \nu_1, & \nu_2, & \nu_3, & \nu_4 \end{vmatrix}$$

the systems of values

$$(i) \quad \begin{vmatrix} 0, & 0, & 0, & 0 \\ 0, & 0, & 0, & 0 \\ 0, & 0, & 0, & 0 \end{vmatrix}$$

* This very symmetrical formula is, it would seem, nearly the same as that employed by Jacobi in his Lectures on Elliptic Functions at the University of Königsberg (see his letter to M. Hermite in Crelle's Journal, vol. xxxii. p. 177). It may be proved by actually

multiplying the four Theta series, and transforming the indices of $-1, e^{i\pi\omega}$, and $e^{\frac{i\pi}{a}}$ in the general term of the product by means of the elementary formulæ

$$a^2 + b^2 + c^2 + d^2 = (s-a)^2 + (s-b)^2 + (s-c)^2 + (s-d)^2,$$

$$aa + b\beta + c\gamma + d\delta = (s-a)(\Sigma - a) + (s-b)(\Sigma - \beta) + (s-c)(\Sigma - \gamma) + (s-d)(\Sigma - \delta),$$

where $2s = a + b + c + d$, $2\Sigma = \alpha + \beta + \gamma + \delta$.

$$(ii) \quad \begin{vmatrix} x, & x, & 0, & 0 \\ 1, & 1, & 0, & 0 \\ 1, & 1, & 0, & 0 \end{vmatrix}$$

$$(iii) \quad \begin{vmatrix} x, & x, & 0, & 0 \\ 0, & 0, & 0, & 0 \\ 1, & 1, & 0, & 0 \end{vmatrix}$$

we obtain successively

$$\kappa^2 + \kappa'^2 = 1, \dots \dots \dots (15)$$

$$\kappa' \theta_{1,0}^2(x) = \theta_{1,1}^2(x) + \kappa \theta_{0,1}^2(x), \dots \dots \dots (16)$$

$$\kappa' \theta_{0,0}^2(x) = \theta_{0,1}^2(x) + \kappa \theta_{1,1}^2(x), \dots \dots \dots (17)$$

Again, attributing to the same elements the values

$$\begin{vmatrix} x+y, & x-y, & 0, & 0 \\ 0, & 1, & 1, & 0 \\ 1, & -1, & 0, & 0 \end{vmatrix}$$

we find

$$\begin{aligned} & \theta_{1,1}(x-y) \theta_{0,1}(x+y) \theta_{1,0}(0) \theta_{0,0}(0) \\ &= \theta_{1,1}(x) \theta_{0,1}(x) \theta_{0,0}(y) \theta_{1,0}(y) \\ & - \theta_{0,0}(x) \theta_{1,0}(x) \theta_{1,1}(y) \theta_{0,1}(y). \end{aligned}$$

Dividing by y , and diminishing y without limit, we obtain

$$\frac{d}{dx} \left(\frac{\theta_{1,1}(x)}{\theta_{0,1}(x)} \right) = \frac{\theta_{0,1}(0) \theta'_{1,1}(0)}{\theta_{1,0}(0) \theta_{0,0}(0)} \frac{\theta_{1,0}(x) \theta_{0,0}(x)}{\theta_{0,1}^2(x)}, \dots \dots \dots (18)$$

Similarly, we might form the differential coefficient of any other quotient of two Theta functions; of these we require only the two following:—

$$\frac{d}{dx} \left(\frac{\theta_{1,0}(x)}{\theta_{0,1}(x)} \right) = \frac{\theta_{0,0}(0) \theta'_{1,1}(0)}{\theta_{1,0}(0) \theta_{0,1}(0)} \frac{\theta_{1,1}(x) \theta_{0,0}(x)}{\theta_{0,1}^2(x)}, \dots \dots \dots (18a)$$

$$\frac{d}{dx} \left(\frac{\theta_{0,0}(x)}{\theta_{0,1}(x)} \right) = \frac{\theta_{1,0}(0) \theta'_{1,1}(0)}{\theta_{0,0}(0) \theta_{0,1}(0)} \frac{\theta_{1,0}(x) \theta_{1,1}(x)}{\theta_{0,1}^2(x)}, \dots \dots \dots (18b)$$

We shall now attribute to α , which has hitherto been left indeterminate, the value $2K$, K being a constant, the square root of which is determined by the equation

$$\sqrt{\frac{2K}{\pi}} = \theta_{0,0}(0) = \sum_{-\infty}^{+\infty} q^{m^2} = \prod_m \frac{1}{1 - q^{2m}} (1 + q^{2m-1})^2; \dots \dots \dots (19)$$

we shall also write K' for $\frac{\omega K}{i}$. Attending to the values of $\sqrt{\kappa'}$ and $\sqrt{\kappa}$, we find from (10) and (11),

$$\sqrt{\frac{2\kappa'K}{\pi}} = \theta_{0,1}(0) = \sum_{-\infty}^{+\infty} (-1)^m q^{m^2} = \prod_m \frac{1}{1 - q^{2m}} (1 - q^{2m-1})^2, \dots \dots \dots (20)$$

$$\sqrt{\frac{2\kappa K}{\pi}} = \theta_{1,0}(0) = \sum_{-\infty}^{+\infty} q^{\frac{1}{4}(2m+1)^2} = 2q^{\frac{1}{4}} \prod_m \frac{1}{1 - q^{2m}} (1 + q^{2m})^2. \dots \dots \dots (21)$$

Multiplying together the infinite products (19), (20), (21), and reducing by an identity of Euler's,

$$\prod_m \frac{1}{1 - q^{2m-1}} = \prod_m \frac{1}{1 + q^m}, \dots \dots \dots (E)$$

we obtain also

$$\sqrt{\frac{2\kappa\kappa'K}{\pi}} = \frac{\pi}{K} q^{\frac{1}{2}} \prod_{m=1}^{\infty} (1 - q^{2m})^3 = \frac{\pi}{2K} \sum_{m=-\infty}^{+\infty} (-1)^m (2m+1) q^{\frac{1}{4}(2m+1)^2} = \frac{1}{i} \theta'_{1,1}(0) \quad (22)$$

These equations (19–22) are of great importance in the arithmetical applications of the theory.

The constant a having the particular value $2K$, the functions

$$\theta_{0,0}(x), \theta_{0,1}(x), \theta_{1,0}(x), \frac{1}{i} \theta_{1,1}(x)$$

are denoted by Jacobi by the symbols $\Theta_1(x)$, $\Theta(x)$, $H_1(x)$, $H(x)$; we shall find it convenient occasionally to employ this notation.

The elliptic functions (properly so called), $\sin amx$, $\cos amx$, Δamx , are defined by the equations

$$\sin amx = \frac{1}{\sqrt{\kappa}} \frac{H(x)}{\Theta(x)}; \quad \cos amx = \frac{\sqrt{\kappa'} H_1(x)}{\sqrt{\kappa} \Theta(x)}; \quad \Delta amx = \sqrt{\kappa'} \frac{\Theta_1(x)}{\Theta(x)}. \quad (23)$$

These functions are all doubly periodic, having for their periods $4K$, $2iK'$; $4K$, $4iK'$; $2K$, $4iK'$ respectively; introducing them into the equations (16–18), we obtain

$$\left. \begin{aligned} \cos^2 amx + \sin^2 amx &= 1, \\ \Delta^2 amx + \kappa^2 \sin^2 amx &= 1, \end{aligned} \right\} \quad \dots \dots \dots (24)$$

$$\left. \begin{aligned} \frac{d \sin amx}{dx} &= \cos amx \Delta amx, \\ \frac{d \cos amx}{dx} &= -\sin amx \Delta amx, \\ \frac{d \Delta amx}{dx} &= -\kappa^2 \sin amx \cos amx. \end{aligned} \right\} \quad \dots \dots \dots (25)$$

From these formulæ it appears that if $y = \sin amx$, x is one of the values of the integral $\int_0^y \frac{dy}{\sqrt{(1-y^2)(1-\kappa^2 y^2)}}$. All the values of that integral are represented by the formula $x + 4mK + 2m'iK'$, in which m and m' represent any integral numbers whatever. Since $\sin amK = 1$, K is one of the values of the integral $\int_0^1 \frac{dy}{\sqrt{(1-y^2)(1-\kappa^2 y^2)}}$; and it can be proved that K' is one of the values of the integral $\int_0^1 \frac{dy}{\sqrt{(1-y^2)(1-\kappa'^2 y^2)}}$. When the real part of ω vanishes (in which case q , K , K' , κ , κ' are real and positive, and κ , κ' less than unity), K and K' are the ordinary values of those definite integrals; *i. e.* the values obtained by causing y to pass from the inferior to the superior limit, through a series of real values.

The well-known formulæ of Addition and Subtraction which express the elliptic functions of the sum or difference of two arguments in terms of the elliptic functions of the arguments themselves, are easily deduced from (13). But as we shall not require these formulæ in the following articles, we may omit them here.

125. *The Modulus and its Complement.*—*The Theory of Transformation.*—In the arithmetical application of the theory, the functions κ and κ' , which are respectively termed the *modulus* of the elliptic functions, and the *complement* of the modulus are of primary importance. They are respectively fourth powers of the quantities

$$u = \sqrt{2} q^{\frac{1}{8}} \prod_m \frac{1+q^{2m}}{1+q^{2m-1}}; \quad u' = \prod_m \frac{1-q^{2m-1}}{1+q^{2m-1}}; \quad \dots \quad (26)$$

which are themselves perfectly determinate functions of ω , if we understand the positive square root of 2 by $\sqrt{2}$, and $\varepsilon^{\frac{i\pi}{8}}$ by $q^{\frac{1}{8}}$. Of these functions, which we shall designate by $\phi(\omega)$ and $\psi(\omega)$, the following equivalent expressions have been given by Jacobi (Crelle's Journal, vol. xxxvii. p. 75-77).

$$\left. \begin{aligned} u &= \sqrt{2} q^{\frac{1}{8}} \prod \frac{1-q^{4m}}{(1+q^{2m-1})(1-q^{2m})} \\ &= \sqrt{2} q^{\frac{1}{8}} \frac{\Sigma(-1)^m q^{\frac{1}{2}m^2+2m}}{\Sigma(-1)^{\frac{1}{2}m(m+1)} q^{\frac{1}{2}(3m^2+m)}}; \\ u &= \sqrt{2} q^{\frac{1}{8}} \prod \frac{(1+q^{4m-2})(1-q^{8m})}{(1+q^{2m-1})(1-q^{4m})} \\ &= \sqrt{2} q^{\frac{1}{8}} \frac{\Sigma q^{4m^2+2m}}{\Sigma q^{2m^2+m}} = \sqrt{2} \frac{\theta_{1,0}(0, \omega)}{\theta_{1,0}\left(0, \frac{\omega}{2}\right)}; \\ u &= \sqrt{2} q^{\frac{1}{8}} \prod \frac{(1-q^{2m-1})(1-q^{4m})}{(1-q^{4m-2})^2(1-q^{4m})} \\ &= \sqrt{2} q^{\frac{1}{8}} \frac{\Sigma(-1)^m q^{2m^2+m}}{\Sigma(-1)^m q^{m^2}} = \frac{\varepsilon^{-\frac{i\pi}{8}} \theta_{1,0}\left(0, \frac{\omega+1}{2}\right)}{\sqrt{2} \theta_{0,1}(0, 2\omega)}; \\ u &= \sqrt{2} q^{\frac{1}{8}} \prod \frac{(1+q^{2m-1})(1-q^{4m})}{(1+q^{2m-1})^2(1-q^{2m})} \\ &= \sqrt{2} q^{\frac{1}{8}} \frac{\Sigma q^{2m^2+m}}{\Sigma q^{m^2}} = \frac{1}{\sqrt{2}} \frac{\theta_{1,0}\left(0, \frac{\omega}{2}\right)}{\theta_{0,0}(0, \omega)}; \\ u' &= \prod \frac{1-q^m}{(1+q^{2m-1})(1-q^{2m})} \\ &= \frac{\Sigma(-1)^m q^{\frac{1}{2}(3m^2+m)}}{\Sigma(-1)^{\frac{1}{2}m(m+1)} q^{\frac{1}{2}(3m^2+m)}}; \\ u' &= \prod \frac{(1-q^{2m-1})(1-q^{4m})}{(1+q^{2m-1})(1-q^{4m})} \\ &= \frac{\Sigma(-1)^m q^{2m^2+m}}{\Sigma q^{2m^2+m}} = \varepsilon^{-\frac{i\pi}{8}} \frac{\theta_{1,0}\left(0, \frac{\omega+1}{2}\right)}{\theta_{1,0}\left(0, \frac{\omega}{2}\right)}; \\ u' &= \prod \frac{(1-q^{2m-1})^2(1-q^{2m})}{(1-q^{4m-2})^2(1-q^{4m})} \\ &= \frac{\Sigma(-1)^m q^{m^2}}{\Sigma(-1)^m q^{2m^2}} = \frac{\theta_{0,1}(0, \omega)}{\theta_{0,1}(0, 2\omega)}; \\ u' &= \prod \frac{(1-q^{4m-2})^2(1-q^{4m})}{(1+q^{2m-1})^2(1-q^{2m})} \\ &= \frac{\Sigma(-1)^m q^{2m^2}}{\Sigma q^{m^2}} = \frac{\theta_{0,1}(0, 2\omega)}{\theta_{0,0}(0, \omega)}. \end{aligned} \right\} \quad (27)$$

$$\left. \begin{aligned} u' &= \prod \frac{1-q^m}{(1+q^{2m-1})(1-q^{2m})} \\ &= \frac{\Sigma(-1)^m q^{\frac{1}{2}(3m^2+m)}}{\Sigma(-1)^{\frac{1}{2}m(m+1)} q^{\frac{1}{2}(3m^2+m)}}; \\ u' &= \prod \frac{(1-q^{2m-1})(1-q^{4m})}{(1+q^{2m-1})(1-q^{4m})} \\ &= \frac{\Sigma(-1)^m q^{2m^2+m}}{\Sigma q^{2m^2+m}} = \varepsilon^{-\frac{i\pi}{8}} \frac{\theta_{1,0}\left(0, \frac{\omega+1}{2}\right)}{\theta_{1,0}\left(0, \frac{\omega}{2}\right)}; \\ u' &= \prod \frac{(1-q^{2m-1})^2(1-q^{2m})}{(1-q^{4m-2})^2(1-q^{4m})} \\ &= \frac{\Sigma(-1)^m q^{m^2}}{\Sigma(-1)^m q^{2m^2}} = \frac{\theta_{0,1}(0, \omega)}{\theta_{0,1}(0, 2\omega)}; \\ u' &= \prod \frac{(1-q^{4m-2})^2(1-q^{4m})}{(1+q^{2m-1})^2(1-q^{2m})} \\ &= \frac{\Sigma(-1)^m q^{2m^2}}{\Sigma q^{m^2}} = \frac{\theta_{0,1}(0, 2\omega)}{\theta_{0,0}(0, \omega)}. \end{aligned} \right\} \quad (28)$$

These expressions of u and u' may be verified by a comparison of their general factors with the general factors in the formulæ (26): for some of them, this comparison requires the Eulerian identity already cited (E). Limits of Π and Σ are $1, +\infty$, and $-\infty, +\infty$; the transformation of the products into sums is effected by means of (7).

If $\omega = a + bi$, and if the positive quantity b increases without limit, a remaining finite, we infer, from (26), that

$$\lim \psi(a + bi) = +1, \lim \frac{\phi(a + bi)}{\sqrt{2}e^{-\frac{b\pi}{8}}} = \cos \frac{a\pi}{8} + i \sin \frac{a\pi}{8}.$$

We shall presently see that $\phi(\omega) = \psi\left(-\frac{1}{\omega}\right)$; hence if $\omega = \frac{i}{b}$ and b increase

without limit, $\lim \phi\left(\frac{i}{b}\right) = \lim \psi(bi) = +1$, $\lim \psi\left(\frac{i}{b}\right) = \lim \phi(ib) = 0$,

$$\lim \frac{\psi\left(\frac{i}{b}\right)}{\sqrt{2}e^{-\frac{b\pi}{8}}} = 1.$$

The principal properties of $(\phi)\omega$ and $\psi(\omega)$ are deducible from the Theory of the Transformation of Elliptic Functions. The general problem considered in that theory is “Given $\omega = \frac{c + d\Omega}{a + b\Omega}$, where a, b, c, d are positive or negative integral numbers, to express the Theta functions containing Ω by means of the Theta functions containing ω .” The determinant $ad - bc$ must be different from zero and positive, because the coefficients of i in the imaginary parts of ω and Ω must both be different from zero and positive; if $ad - bc = n$, the transformation is said to be of order n . Let $\Lambda, \Lambda', \lambda, \lambda', v, v'$ be the same functions of Ω that $K, K', \kappa, \kappa', u, u'$ are of ω ; since $\Omega = i \frac{\Lambda'}{\Lambda}$, $\omega = i \frac{K'}{K}$, the equation $\omega = \frac{c + d\Omega}{a + b\Omega}$ implies the existence of two others of the form

$$\left. \begin{aligned} \frac{1}{M} K &= a\Lambda + bi\Lambda', \\ \frac{1}{M} iK' &= c\Lambda + di\Lambda'; \end{aligned} \right\} \dots \dots \dots (29)$$

in which M is a coefficient termed the *multiplier*; when Λ has been found, M is determined by the equation

$$\frac{1}{M} = \frac{\Lambda}{K} (a + b\Omega) = \frac{\Lambda}{iK'} (c + d\Omega); \dots \dots \dots (30)$$

it also satisfies the relation

$$M^2 = \frac{1}{n} \frac{\lambda(1 - \lambda^2)}{\kappa(1 - \kappa^2)} \cdot \frac{d\kappa}{d\lambda} * \dots \dots \dots (31)$$

If $n=1$, the theory of the transformations of the first order has been comprised by M. Hermite in the single formula†,

* Fundamenta Nova, p. 75.

† Liouville, New Series, vol. iii. p. 26; and, with less detail, in the Comptes Rendus, vol. xlv. p. 171.

$$\theta_{\mu, \nu} \left(\frac{x}{M}, \Omega \right) = \frac{J \delta_{\mu, \nu}}{\sqrt{-i(a+b\Omega)}} \varepsilon^{\frac{\frac{1}{2}i\pi b x^2}{K\Lambda M^{\frac{1}{4}}}} \theta_{m, n}(x, \omega), \quad \dots \quad (32)$$

in which

$$m = a\mu + b\nu + ab,$$

$$n = c\mu + d\nu + cd.$$

$$\delta_{\mu, \nu} = \varepsilon^{-\frac{i\pi}{4}(ac\mu^2 + 2bc\mu\nu + bd\nu^2 + 2abc\mu + 2abd\nu + ab^2c)},$$

$$J = \frac{1}{\sqrt{b}} \sum_0^{b-1} \varepsilon^{-\frac{i\pi}{b} a(s - \frac{1}{2}b)^2}$$

$$= \left(\frac{b}{a} \right) i^{-\frac{1}{2}a}, \text{ if } a \text{ is uneven,}$$

or

$$= \left(\frac{a}{b} \right) i^{-\frac{1}{2}a} \times i^{-\frac{1}{2}(a-1)(b-1)}, \text{ if } b \text{ is uneven}^*;$$

the radical $\sqrt{-i(a+b\Omega)}$ represents that square root of $-i(a+b\Omega)$, of which the real part is positive; lastly, Λ is determined by the equation

$$\sqrt{\frac{2\Lambda}{\pi}} = \theta_{0,0}(0, \Omega) = \frac{J \delta_{0,0}}{\sqrt{-i(a+b\Omega)}} \theta_{ab, cd}(0, \omega), \quad \dots \quad (33)$$

which is a particular case of the formula (32); and M by the equation

$$\frac{1}{M} = iJ^2 \delta_{0,0}^2 \frac{\theta_{ab, cd}^2(0, \omega)}{\theta_{0,0}^2(0, \omega)}. \quad \dots \quad (34)$$

The formula supposes that b is different from zero and positive; if $b=0$, we may suppose $a=d=1$, so that $\omega=c+\Omega$, and the formula of transformation is

$$\theta_{\mu, \nu} \left(\frac{x}{M}, \Omega \right) = \varepsilon^{-\frac{i\pi}{4} c \mu^2} \theta_{\mu, c\mu+c+\nu}(x, \omega), \quad \dots \quad (35)$$

where

$$\frac{1}{M} = \frac{\theta_{0,c}^2(0, \omega)}{\theta_{0,0}^2(0, \omega)}.$$

The equations of the annexed Table, which, for any transformation of the first order, express the relation subsisting between the given and the transformed modulus, are also due to M. Hermite, and are of great importance in the theory of the functions $\phi(\omega)$ and $\psi(\omega)$ †. They may be obtained by applying the formula of transformation (32) to the expressions of $\phi(\omega)$ given by Jacobi (27). There are six cases, answering to the six solutions, of which the congruence $ad-bc \equiv 1, \text{ mod } 2$ is susceptible. We add, in each case, the value of the multiplier.

* These determinations of the value of J coincide with those given by M. Hermite in Liouville's Journal, vol. iii. p. 29; where, however, it would seem that the formulæ relating to the two cases of " α pair" and " α impair" ought to be transposed.

† "Sur la résolution de l'équation du cinquième degré," Comptes Rendus, vol. xlv. p. 508; or in a separate reprint (including other memoirs from vols. xlv. and xlviii.) with the title "Sur la théorie des équations modulaires, et la résolution de l'équation du cinquième degré," p. 4.

TABLE A.

$$\omega = \frac{c+d\Omega}{a+b\Omega}; \quad ad-bc=1.$$

| | $a \equiv$ | $b \equiv$ | $c \equiv$ | $d \equiv$ | $\phi(\omega) =$ | $\frac{1}{M} =$ |
|------|------------|------------|------------|------------|--|---------------------------------|
| I. | 1 | 0 | 0 | 1 | $\left(\frac{2}{d}\right) \varepsilon^{\frac{i\pi}{8} cd} \phi(\Omega)$ | $(-1)^{\frac{a-1}{2}}$ |
| II. | 0 | 1 | 1 | 0 | $\left(\frac{2}{c}\right) \varepsilon^{-\frac{i\pi}{8} cd} \psi(\Omega)$ | $(-1)^{\frac{b-1}{2}} i$ |
| III. | 1 | 1 | 0 | 1 | $\left(\frac{2}{d}\right) \varepsilon^{-\frac{i\pi}{8} cd} \frac{1}{\phi(\Omega)}$ | $(-1)^{\frac{a+c-1}{2}} \kappa$ |
| IV. | 1 | 1 | 1 | 0 | $\left(\frac{2}{c}\right) \varepsilon^{\frac{i\pi}{8} cd} \frac{1}{\psi(\Omega)}$ | $(-1)^{\frac{c+1}{2}} i\kappa$ |
| V. | 1 | 0 | 1 | 1 | $\varepsilon^{\frac{i\pi}{8} cd} \frac{\phi(\Omega)}{\psi(\Omega)}$ | $(-1)^{\frac{a-1}{2}} \kappa'$ |
| VI. | 0 | 1 | 1 | 1 | $\varepsilon^{-\frac{i\pi}{8} cd} \frac{\psi(\Omega)}{\phi(\Omega)}$ | $(-1)^{\frac{b-1}{2}} i\kappa'$ |

It would be easy to write these equations so as to express $\phi(\Omega)$ in terms of $\phi(\omega)$, thus completing the solution of the Problem of Transformation of the first order; but it is more convenient to retain them in their actual form. Similar formulæ exist expressing $\psi(\omega)$, $\frac{\phi(\omega)}{\psi(\omega)}$, in terms of $\phi(\Omega)$ and $\psi(\Omega)^*$.

The propositions implied in the equations of the Table may also be enunciated conversely. Thus to case I. corresponds the theorem "If ω and Ω are imaginaries in which the coefficient of i is positive, and if $\phi^{2\nu}(\omega) = \phi^{2\nu}(\Omega)$, where $\nu = 1, 2$, or 3 , four integral numbers a, b, c, d can be found satisfying the relations $\omega = \frac{c+d\Omega}{a+b\Omega}$; $ad-bc=1$; $a \equiv d \equiv 1, \text{ mod } 2$; $b \equiv 0, \text{ mod } 2$; $c \equiv 0, \text{ mod } 2^{4-\nu}$."

"If $\phi(\omega) = \phi(\Omega)$, four integral numbers a, b, c, d can be found satisfying the relations $\omega = \frac{c+d\Omega}{a+b\Omega}$; $ad-bc=1$; $b \equiv 0, \text{ mod } 2$; and either $a \equiv d \equiv \pm 1, \text{ mod } 8$, $c \equiv 0, \text{ mod } 16$, or $a \equiv d \equiv \pm 3, \text{ mod } 8$, $c \equiv 8, \text{ mod } 16$."

* M. Hermite has also shown that the function

$$\chi(\omega) = \sqrt[6]{2} \cdot q^{\frac{1}{24}} (1-q)(1+q^2)(1-q^3)(1+q^4) \dots,$$

which is a cube root of $\phi(\omega) \times \psi(\omega)$, possesses a similar property; viz. if $\omega = \frac{c+d\Omega}{a+b\Omega}$, $ad-bc=1$, $\chi(\omega)$ can be expressed in terms of $\chi(\Omega)$, $\phi(\Omega)$, and $\psi(\Omega)$. (Sur la théorie des équations Modulaires, p. 15.)

These converse propositions may be demonstrated by means of the differential equations satisfied by the elliptic functions; by a similar process we obtain the following equally important theorem:—

“If A is any quantity, real or imaginary, other than zero or positive unity, there exist values of ω , having the coefficient of i in their imaginary parts different from zero and positive, which satisfy the equation $\phi^s(\omega)=A$.”

When n is an uneven integer other than 1, the formula of transformation is

$$\theta_{\mu, \nu} \left(\frac{x}{M}, \Omega \right) = T \epsilon^{-\frac{ib\pi x^2}{K\Lambda M}} \theta_{m, n}(x, \omega), \quad (36)$$

in which m and n are determined as before, and T is a homogeneous function of order $\frac{n-1}{2}$ of the squares of two of the functions $\theta_{\mu, \nu}(x, \omega)$. We need

not occupy ourselves here with the determination of Λ and T , but shall confine ourselves to the consideration of the modulus and multiplier alone. Representing by $\Phi(n)$ the sum of the divisors of n , every binary matrix of

order n is included in the formula $\begin{vmatrix} a, b \\ c, d \end{vmatrix} = |\Delta| \times |\epsilon|$, in which $|\epsilon|$ is an unit

matrix, and $|\Delta|$ one of the $\Phi(n)$ matrices $\begin{vmatrix} \gamma, 0 \\ k, \gamma' \end{vmatrix}$, γ and γ' being conjugate

divisors of n , and k representing any term of a complete system of residues, mod γ' . It is thus sufficient to consider a system of $\Phi(n)$ transformations of order n , since all others arise from compounding transformations of the first order with the transformations of that system. If we take, in particular, the

system of transformations, $\omega = \frac{-16k + \gamma'\Omega}{\gamma}$, corresponding to the matrices

$\begin{vmatrix} \gamma, 0 \\ -16k, \gamma' \end{vmatrix}$ (since n , and therefore γ' is uneven, we may take a system of residues, mod γ' , of which every term is divisible by 16), we have for the determination of the transformed modulus, the fundamental theorem*,

“The quantities $\left(\frac{2}{\gamma}\right)\phi(\Omega) = \left(\frac{2}{\gamma}\right)\phi\left(\frac{\gamma\omega + 16k}{\gamma'}\right)$ are the roots of an equation of order $\Phi(n)$, in which the first coefficient is unity, and the other coefficients are rational and integral functions of $\phi(\omega)$ having integral coefficients.”

This equation is termed the modular equation of the transformations of the n th order; designating $\phi(\omega)$ by u , and $\left(\frac{2}{\gamma}\right)\phi\left(\frac{\gamma\omega + 16k}{\gamma'}\right)$ by v , we shall represent it by $f(n, u, v) = 0$, or more simply by $f(u, v) = 0$. The function $f(u, v)$ is characterized by the following, among many other properties,

$$\left. \begin{aligned} f(u, v) &= (-1)^{\Phi(n)} \Pi \left(\frac{2}{\gamma} \right) \times f \left(\left(\frac{2}{n} \right) v, u \right), \\ f(u, v) &= (-1)^{\Phi(n)} \Pi \left(\frac{2}{\gamma} \right) \times (uv)^{\Phi(n)} f \left(\frac{1}{u}, \frac{1}{v} \right). \end{aligned} \right\} (37)$$

* M. Hermite, Sur la théorie des équations Modulaires, p. 36; M. Joubert, Comptes Rendus, vol. 1. p. 774; or, in a separate reprint with the title “Sur la Théorie des Fonctions Elliptiques, et son application à la Théorie des Nombres,” p. 21. The demonstration of this theorem for the case in which n is a prime, is contained in Sohnke's important memoir “Æquationes modulares pro transformatione functionum ellipticarum,” Crelle, vol. xvi. p. 97. From this particular case, the truth of the theorem for any value of n is inferred without difficulty.

If in the equation $f(u, v)=0$ we put $u=\psi(\omega)$, the roots are represented by $\left(\frac{2}{\gamma'}\right)\psi\left(\frac{\gamma\omega+16k}{\gamma'}\right)$.

If we put $u=\epsilon^{s\frac{i\pi}{4}}\phi(\omega)$, where s is any integral number, the roots are represented by $\left(\frac{2}{\gamma'}\right)\epsilon^{ns\frac{i\pi}{4}}\phi\left(\frac{\gamma\omega+16k}{\gamma'}\right)$. If $u=\epsilon^{s\frac{i\pi}{4}}$, there are γ' roots represented

by $\left(\frac{2}{\gamma'}\right)\epsilon^{ns\frac{i\pi}{4}}$, γ denoting any divisor of n . If we put $u=\epsilon^{s\frac{i\pi}{8}}\frac{\phi(\omega)}{\psi(\omega)}$, where s is any uneven number, the roots are represented by $\left(\frac{2}{n}\right)\epsilon^{ns\frac{i\pi}{8}}\frac{\phi\left(\frac{\gamma\omega+16k}{\gamma'}\right)}{\psi\left(\frac{\gamma\omega+16k}{\gamma'}\right)^*}$.

The equations whose roots are respectively the squares, fourth powers, and eighth powers of the roots of $f(u, v)=0$, contain only the squares, fourth powers, and eighth powers of u ; we shall represent these modular equations by $f_2(u^2, v^2)=0$, $f_4(u^4, v^4)=0$, or $f_4(\kappa, \lambda)=0$, and $f_8(u^8, v^8)=0$, or $f_8(\kappa^2, \lambda^2)=0$. The last equation (by what has preceded) remains unchanged if we write (1) κ for λ , and *vice versa*, (2) $1-\kappa^2$ for κ^2 , $1-\lambda^2$ for λ^2 , (3) $\frac{1}{\kappa}$ for κ , $\frac{1}{\lambda}$ for λ .

If n admits of a square divisor δ^2 , $f(n, u, v)$ is divisible by $f\left(\frac{n}{\delta^2}, u, \left(\frac{2}{\delta}\right)v\right)$; for if $\gamma\gamma'=\frac{n}{\delta^2}$, $v=\left(\frac{2}{\gamma'}\right)\phi\left(\frac{\gamma\omega+16k}{\gamma'}\right)$ is a root of $f\left(\frac{n}{\delta^2}, u, v\right)=0$, and $\left(\frac{2}{\gamma\delta}\right)\phi\left(\frac{\gamma\delta\omega+16k\delta}{\delta\gamma'}\right)=\left(\frac{2}{\delta}\right)v$ is a root of $f(n, u, v)=0$.

It is sometimes convenient to suppose that the modular equation has been freed by division from the factors corresponding to the quotients of n divided by its square divisors; its degree will then be

$$\Phi(n)-\Sigma\Phi\left(\frac{n}{p^2}\right)+\Sigma\Phi\left(\frac{n}{p_1^2p_2^2}\right)-\dots\dots\dots$$

if $p_1, p_2, \dots$ represent the primes whose squares divide n , or $n\Pi\left(1+\frac{1}{p}\right)$, if p represent any prime dividing n . The roots of this reduced modular equation are expressed by the same formula as before; only that γ, γ' , and k are now subject to the condition that they must not have any common divisor.

With regard to transformations of an even order, we shall only have occasion to consider the case in which n is a power of 2. If $n=2$, we have the modular equations,

$$v^4=\frac{2u^2}{1+u^4}, \quad v'^4=\frac{1-u^4}{1+u^4}, \quad \dots\dots\dots (38)$$

of which, if $u=\phi(\omega)$, the roots are given by the equations $v^4=\phi^4\left(\frac{\omega}{2}\right)$,

* It is easily seen that $v=\phi(\omega)$ is one of the roots of $f\left[\left(\frac{2}{\gamma'}\right)\phi\left(\frac{\gamma\omega+16k}{\gamma'}\right), v\right]=0$: this establishes the first of the equations (37). The other properties given in the text are deducible from the equations $u=\phi(\omega)$, $v=\left(\frac{2}{\gamma'}\right)\phi\left(\frac{\gamma\omega+16k}{\gamma'}\right)$, by applying to ω different transformations of the first order, and employing the formulæ of the Table A.

$v^4 = \psi^4 \left(\frac{\omega}{2} \right)$. If we represent the modular equation of order 2^μ , when cleared of fractions, by $f(2^\mu, u, v_\mu) = 0$, the modular equation of order $2^{\mu+1}$, or $f(2^{\mu+1}, u, v_{\mu+1}) = 0$, is obtained by eliminating v_μ from the two equations $f(2^\mu, u, v_\mu) = 0$, and $v_{\mu+1}^4 = \frac{2v_\mu^2}{1+v_\mu^4}$. We may thus successively calculate the modular equations of the orders 4, 8, 16, . . . ; and, attending to the expression, by means of the transcendent ϕ , of the roots of the equation $v^4 = \frac{2u^2}{1+u^4}$, we may establish the following properties:—the function $f(2^\mu, u, v_\mu)$ is of the order $2^{\mu-2}$ in v^8 , and of the order 2^μ in u^2 ; the coefficient of $u^{2\mu+1}$ is $v^{2\mu+1}$, and the equation is not altered by writing $\frac{1}{u^2}$ for u^2 and multiplying by $u^{2\mu+1}$; if $u = \phi(\omega)$, the values of v are given by the equation

$$v^8 = \phi^8 \left(\frac{\omega + 8k}{2^\mu} \right), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (39)$$

in which k represents any term of a complete system of residues, mod $2^{\mu-2}$, and correspond to the transformations defined by the formula

$$\omega = \frac{c+d\Omega}{a+b\Omega}, \quad \left| \begin{matrix} a, b \\ c, d \end{matrix} \right| = \left| \begin{matrix} 1, 0 \\ -8k, 2^\mu \end{matrix} \right| \times \left| \begin{matrix} 1, 0 \\ 2h, 1 \end{matrix} \right|,$$

where h is any term of a system of residues, mod 8; if $v = \phi(\Omega)$, the values of u are given by the equation

$$u^2 = \phi^2 \left(\frac{2^\mu \Omega}{1+2h\Omega} \right), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (40)$$

where h is any term of a system of residues, mod 2^μ .

For the determination of the multiplier in a transformation of an uneven order n , we have the theorem,

“If M is the multiplier corresponding to the transformation $\omega = \frac{-16k + \gamma'\Omega}{\gamma}$, the $\Phi(n)$ quantities $z = (-1)^{\frac{\gamma-1}{2}} \frac{1}{M}$ satisfy an equation of order $\Phi(n)$, in which the coefficient of the highest power of z is unity, and the coefficients of the other powers of z are rational and integral functions with integral coefficients of κ^2 ; the absolute term, in particular, being $\pm n$ ”.*

126. *The Complex Multiplication of the Argument.*—The problem of the multiplication of the argument is “Given an integral number n , to express the Theta functions of $n\omega$ and ω by means of the Theta functions of ω and ω .” The solution of this problem may be made to depend on that of the addition of arguments; for to add n equal arguments is to multiply the argument by n . The problem is also included in that of transformation; for if we consider the transformation of order n^2 , of which the matrix is $\left| \begin{matrix} n, 0 \\ 0, n \end{matrix} \right|$, we have $\Omega = \omega$,

$$\Lambda = K, \quad \Lambda' = K', \quad \frac{1}{M} = n.$$

When ω is not the root of a quadratic equation having integral coefficients,

* Jacobi in Crelle's Journal, vol. iii. p. 308. M. Joubert (Comptes Rendus, vol. xlvii. p. 341) has calculated the equations of the multiplier for the orders 3, 5, 7, 11. See also M. Brioschi in Tortolini's Annals, vol. i. (New Series) p. 175, M. Hermite, Equations Modulaires, pp. 12 and 31. No completed demonstration of the theorem appears to have been given.

the transformations, of any square order n^2 , and of the type $\begin{vmatrix} n, 0 \\ 0, n \end{vmatrix}$ are the only transformations which do not alter the value of ω . For if $\omega = \frac{c+d\Omega}{a+b\Omega}$, and $\omega = \Omega$, we have $b\omega^2 + (a-d)\omega - c = 0$. But, by hypothesis, ω is not the root of any quadratic equation having integral coefficients; neither is ω rational; therefore the three numbers b , $a-d$, and c are all zero, and the matrix $\begin{vmatrix} a, b \\ c, d \end{vmatrix}$ is of the type $\begin{vmatrix} n, 0 \\ 0, n \end{vmatrix}$. But if ω is the root of a quadratic equation having integral coefficients, an infinite number of transformations, other than those included in the formula $\begin{vmatrix} n, 0 \\ 0, n \end{vmatrix}$, can be assigned, which do not alter the value of ω . Let $A + 2B\omega + C\omega^2 = 0$ be the equation satisfied by ω ; and let $AC - B^2 = \Delta$; then Δ is different from zero and positive; also A and C are of the same sign, and may be supposed to be positive, so that $\omega = \frac{-B + i\sqrt{\Delta}}{C}$; lastly, let $\theta = 1$, or $\theta = 2$, according as (A, B, C) is properly or improperly primitive. Let n be any number such that $\theta^2 n$ admits of representation by $(1, 0, \Delta)$; and let σ, τ be the values of the indeterminates in any such representation; then the transformation

$$\begin{vmatrix} \frac{1}{\theta}(\sigma + \tau B), \frac{\tau C}{\theta} \\ -\frac{\tau A}{\theta}, \frac{1}{\theta}(\sigma - \tau B) \end{vmatrix}$$

of order n will not alter the value of ω , because $\omega = \frac{-\tau A + (\sigma - \tau B)\omega}{\sigma + \tau B + \tau C\omega}$, and will have for the reciprocal of its multiplier

$$\frac{1}{\theta}[\sigma + \tau B + \tau C\omega] = \frac{1}{\theta}(\sigma + i\tau\sqrt{\Delta}).$$

The transformations derived from different values of n , or from different representations of the same value, are all different; and every transformation of order n which does not alter the value of ω , is derived from some representation of $\theta^2 n$ by $(1, 0, \Delta)$; so that the transformations and representations correspond to one another one by one, and are equal in number. It will be observed that the multiplier corresponding to any of these transformations is a complex factor (composed with $\sqrt{-\Delta}$) of the number expressing the order of the transformation; so that the transformation is equivalent to a complex multiplication of the argument. And the Theta functions containing ω do, or do not, admit of complex multiplication, according as ω is or is not a quadratic surd.

If we consider the values of ω contained in Theta functions admitting of multiplication with $i\sqrt{\Delta}$, we see that these values are infinite in number; each form of determinant $-\Delta$ supplying one. But the values of $\phi^s(\omega)$, corresponding to these values, are finite in number, being six times as many as the classes of forms of det. $-\Delta$; provided that in the enumeration of the classes a class of det. -1 , or a class derived from a class of det. -1 , is counted as $\frac{1}{2}$ instead of 1; and an improperly primitive class of det. -3 , or a class derived from such a class, is counted as $\frac{1}{3}$ instead of 1. For it appears from the Table (A) that the values of $\phi^s(\omega)$ corresponding to two equivalent forms, are equal or not, according as the transformation, by which one form passes

into the other, is or is not of the type $\begin{vmatrix} 1, 0 \\ 0, 1 \end{vmatrix}, \text{ mod } 2$. We have therefore only to ascertain how many subclasses each class contains, a subclass consisting of forms equivalent by transformations of the type $\begin{vmatrix} 1, 0 \\ 0, 1 \end{vmatrix}$. A simple discussion shows that the number of subclasses is six (corresponding to the six types of binary matrices for the modulus 2); except in the two cases just referred to, when the number of subclasses is reduced to 3 and 2 respectively, owing to the existence in those two cases of automorphics which are not of the type $\begin{vmatrix} 1, 0 \\ 0, 1 \end{vmatrix}, \text{ mod } 2$. Thus the whole number of values of $\phi^s(\omega)$ is $6G(\Delta)$, $G(\Delta)$ representing the number of classes of det. $-\Delta$, counted in the manner stated above*. It will be seen that the six values of $\phi^s(\omega)$ corresponding to the forms of the same class are of the type $\kappa^2, \frac{1}{\kappa^2}, \frac{1}{1-\kappa^2}, 1-\kappa^2, \frac{\kappa^2-1}{\kappa^2}, \frac{\kappa^2}{\kappa^2-1}$ (being in fact related to one another as the six anharmonic ratios of four points). The three values corresponding to the forms of det. -1 are $-1, 2, \frac{1}{2}$; and the two values corresponding to the improperly primitive forms of det. -3 are the imaginary cube roots of -1 .

It is an important theorem (to which we shall again refer) that the $6G(\Delta)$ values of $\phi^s(\omega)$ satisfy an equation of that order, of which the coefficients are integral numbers (but the first coefficient not, in general, unity).

The whole number of values of $\phi(\omega)$, corresponding to the forms of determinant $-\Delta$, is $48G(\Delta)$. For if a be the value of $\phi(\omega)$ corresponding to any form of a given subclass, and η be any eighth root of unity, ηa will be a value of $\phi(\omega)$ corresponding to another form of the same subclass.

127. *Jacobi's Formulæ for the number of decompositions of a number into squares.*—The first applications of elliptic formulæ to the theory of numbers were made by Jacobi. The developments, in series proceeding by powers of q , of the squares, fourth, sixth, and eighth powers of the functions

$$\sqrt{\frac{2K}{\pi}} = 1 + 2q + 2q^4 + 2q^9 + 2q^{16} + \dots,$$

$$\sqrt{\frac{2\kappa K}{\pi}} = 2q^{\frac{1}{4}} + 2q^{\frac{9}{4}} + 2q^{\frac{25}{4}} + \dots,$$

which are found in the 'Fundamenta Nova' (sections 40–42, and 65, 66), are the analytical expression of arithmetical propositions relating to the composition of numbers by the addition of two, four, six, and eight squares. In these developments n represents any number from 1 to ∞ , ν any uneven number from 1 to ∞ ; d is any divisor of n , δ any uneven divisor of n or any divisor of ν ; d' and δ' are the divisors conjugate to d and δ ; and the summations indicated by $\Sigma_n, \Sigma_\nu, \Sigma_d$, and Σ extend to every value of n, ν, d , and δ respectively.

$$\begin{aligned} (1) \quad \frac{2K}{\pi} &= 1 + 4\Sigma_\nu (-1)^{\frac{\nu-1}{2}} \frac{q^\nu}{1-q^\nu} = 1 + 4\Sigma_n \frac{q^n}{1+q^{2n}} \\ &= 1 + 4\Sigma \Sigma_\delta (-1)^{\frac{\delta-1}{2}} q^n. \end{aligned}$$

* $G(\Delta)$ is the sum of the *densities* of the classes of det. $-\Delta$; the density of a class, according to the definition of Eisenstein, being the reciprocal of the number of its automorphics.

$$(2) \quad \frac{2\kappa K}{\pi} = 4\Sigma_{\nu}(-1)^{\frac{\nu-1}{2}} \frac{q^{\frac{1}{2}\nu}}{1-q^{\nu}} = 4\Sigma_{\nu} \frac{q^{\frac{1}{2}\nu}}{1+q^{\nu}} \\ = 4\Sigma_{\nu} \Sigma_{\delta}(-1)^{\frac{\delta-1}{2}} q^{\frac{\nu}{2}}$$

$$(3) \quad \frac{4K^2}{\pi^2} = 1 + 8\Sigma_n \frac{nq^n}{1+(-1)^n q^n} = 1 + 8\Sigma_n \frac{q^n}{(1+(-1)^n q^n)^2} \\ = 1 + 24\Sigma_n \Sigma_{\delta} \delta q^n - 16\Sigma_{\nu} \Sigma \delta q^{\nu} = 1 + 8[2 - (-1)^n] \Sigma_n \Sigma_{\delta} \delta q^n.$$

$$(4) \quad \frac{4\kappa^2 K^2}{\pi^2} = 16\Sigma_{\nu} \frac{\nu q^{\nu}}{1-q^{2\nu}} = 16\Sigma_{\nu} \frac{q^{\nu}(1+q^{2\nu})}{(1-q^{2\nu})^2} \\ = 16\Sigma_{\nu} \Sigma_{\delta} \delta q^{\nu}.$$

$$(5) \quad \frac{8K^3}{\pi^3} = 1 + 16\Sigma_n \frac{n^2 q^n}{1+q^{2n}} - 4\Sigma_{\nu}(-1)^{\frac{\nu-1}{2}} \frac{\nu^2 q^{\nu}}{1-q^{\nu}} \\ = 1 + 4\Sigma_n \Sigma_{\delta}(-1)^{\frac{\delta-1}{2}} (4\delta'^2 - \delta^2) q^n.$$

$$(6) \quad \frac{8\kappa^3 K^3}{\pi^3} = 4\Sigma_{\nu} \frac{\nu^2 q^{\frac{1}{2}\nu}}{1+q^{\nu}} - 4\Sigma_{\nu}(-1)^{\frac{\nu-1}{2}} \frac{\nu^2 q^{\frac{1}{2}\nu}}{1-q^{\nu}} \\ = 4\Sigma_{\nu} \Sigma_{\delta} [(-1)^{\frac{\delta'-1}{2}} - (-1)^{\frac{\delta-1}{2}}] \delta^2 q^{\frac{1}{2}\nu}$$

$$(7) \quad \frac{16K^4}{\pi^4} = 1 + 16\Sigma_n \frac{n^3 q^n}{1-(-1)^n q^n} \\ = 1 + 16\Sigma_n \Sigma_d (-1)^{n+d} d^3 q^n.$$

$$(8) \quad \frac{16\kappa^4 K^4}{\pi^4} = 256\Sigma_n \frac{n^3 q^{2n}}{1-q^{4n}} \\ = 256\Sigma_n \Sigma \delta'^3 q^{2n}.$$

Of these formulæ, the first two are the analytical expression of the principal theorems relating to the composition of numbers by the addition of two squares (see art. 95 of this Report); the others may be paraphrased as follows*.

(3) "The number of representations of any number N as a sum of four squares is eight times the sum of its divisors if N is uneven, twenty-four times the sum of its uneven divisors if N is even."

(4) "The number of compositions of the quadruple of any uneven number N by the addition of four uneven squares is equal to the sum of the divisors of N."

(5) "The number of representations of any number N as a sum of six squares is $4\Sigma(-1)^{\frac{\delta-1}{2}}(4\delta'^2 - \delta^2)$, δ denoting any uneven divisor of N, δ' its conjugate divisor. In particular if $N \equiv 1, \text{ mod } 4$, the number of representations is $12\Sigma(-1)^{\frac{\delta-1}{2}}\delta^2$; if $N \equiv -1, \text{ mod } 4$, it is $-20\Sigma(-1)^{\frac{\delta-1}{2}}\delta^2$."

(6) "The number of compositions of the double of any uneven number N

* The expansions of (1) $\times$ (2), (1) $\times$ (4), (3) $\times$ (2), (3) $\times$ (4), are also given in sections 40 and 41 of the 'Fundamenta'; and may be similarly interpreted.

by the addition of six uneven squares is $\frac{1}{16}\Sigma[(-1)^{\frac{\delta'-1}{2}} - (-1)^{\frac{\delta-1}{2}}]\delta^2$; if $N \equiv 1$, mod 4, this number is zero; if $N \equiv -1$, mod 4, it is $-\frac{1}{8}\Sigma(-1)^{\frac{\delta-1}{2}}\delta^2$."

(7) The number of representations of any uneven number as a sum of eight squares is sixteen times the sum of the cubes of its divisors; for an even number it is sixteen times the excess of the cubes of the even divisors above the cubes of the uneven divisors."

(8). "If N is any number whatever, the number of compositions of $8N$ by the addition of eight uneven squares is equal to the sum of the cubes of those divisors of N whose conjugates are uneven."

In counting the number of compositions by addition of squares, two compositions are to be considered as different if, and only if, the same places in each are not occupied by the same squares; but in counting the number of representations we have to attend also to the signs of the roots of the squares. Thus each composition by the addition of four squares, none of which is zero, is equivalent to sixteen representations. Only one or two of the preceding theorems are enunciated in the published writings of Jacobi: see Crelle's Journal, vol. iii. p. 191; vol. xii. p. 167. Some of the others have been given by Eisenstein (Crelle, vol. xxxv. p. 135), who had also obtained purely arithmetical demonstrations of them from the theory of quadratic forms containing several indeterminates. "In my investigations," he says, "these theorems are proved by purely arithmetical considerations, and appear as special cases of more general theorems; at the same time we see why these developments close with the eighth power; since, in fact, eight is the greatest number of indeterminates for which only one class of forms, represented by a sum of squares, appertains to the determinant -1 ."

In the second of the notes to which we have just referred (Crelle, vol. xii. p. 167), Jacobi has given an arithmetical demonstration of the theorem (4). It consists in a kind of translation of the analytical proof into an arithmetical one; and is of great interest and importance, as the first example of a new method, and as having suggested important researches to MM. Liouville and Kronecker (see Liouville's Journal, New Series, vol. vii. p. 48; M. Kronecker, 'Monatsberichte,' May 26, 1862, p. 307).

The doubly periodic functions of argument $\frac{2Kx}{\pi}$ obtained by dividing any Theta function by any other, or the product of any two of them, by the product of the other two, admit of development in series proceeding by sines or cosines of multiples of the argument x . These developments, which, unlike the developments of the Theta functions themselves, are not convergent for all values of x , real or imaginary, will be found for the most part in section 39 of the 'Fundamenta Nova'; and the complete system has been given by M. Hermite (Comptes Rendus, July 7, 1862). One, which we require in this place, will serve as an example of the rest,

$$\left. \begin{aligned} \frac{\kappa K}{2\pi} \sin \text{am} \frac{2Kx}{\pi} &= \Sigma_{\nu} \frac{q^{1\nu} \sin \nu x}{1-q^{\nu}} \\ &= \Sigma_{\nu} \Sigma_{\delta} \sin \delta x \cdot q^{1\nu}. \end{aligned} \right\} \dots \dots \dots (A)$$

It is from these developments that the expansions (1) ... (8) of the powers of $\sqrt{\frac{2K}{\pi}}$ and $\sqrt{\frac{2\kappa K}{\pi}}$ are deduced. Thus, writing $\frac{\pi}{2}$ for x in (A), we find, since $\sin \text{am} K=1$,
1865.

$$\frac{\kappa K}{2\pi} = \sum_{\nu} (-1)^{\frac{\nu-1}{2}} \frac{q^{\frac{1}{2}\nu}}{1-q^{\nu}},$$

which is the formula (2). We shall now show how the equation (4) can be obtained by squaring this formula. For this purpose we represent by α and β any two unequal positive uneven numbers congruous to one another for the modulus 4, and by α' and β' any two positive uneven numbers not congruous to one another for the modulus 4. We then have

$$\begin{aligned} \frac{1}{4} \frac{\kappa^2 K^2}{\pi^2} &= \sum_{\nu} \frac{q^{\nu}}{(1-q^{\nu})^2} + \sum_{\alpha} \sum_{\beta} \frac{q^{\frac{1}{2}(\alpha+\beta)}}{(1-q^{\alpha})(1-q^{\beta})} - \sum_{\alpha'} \sum_{\beta'} \frac{q^{\frac{1}{2}(\alpha'+\beta')}}{(1-q^{\alpha'})(1-q^{\beta'})}, \\ &= P + Q - R, \text{ for brevity.} \end{aligned}$$

Here

$$P = \sum_{\nu} \frac{q^{\nu}}{(1-q^{\nu})^2} = \sum_n \cdot \sum \delta'. q^n = \sum_n \frac{nq^n}{1-q^{2n}};$$

again in Q, if we double each term we may suppose $\beta > \alpha$; let $\beta = \alpha + 4n$; observing that α may be any positive uneven number, and n any positive number whatever, we find

$$\begin{aligned} Q &= 2 \sum_n \sum_{\nu} \frac{q^{2n+\nu}}{(1-q^{\nu})(1-q^{4n+\nu})} \\ &= 2 \sum_n \sum_{\nu} \frac{q^{2n}}{1-q^{4n}} \left[\frac{q^{\nu}}{1-q^{\nu}} - \frac{q^{4n+\nu}}{1-q^{4n+\nu}} \right] \\ &= 2 \sum_n \sum_{\nu}^{\frac{4n-1}{1}} \frac{q^{2n+\nu}}{(1-q^{4n})(1-q^{\nu})}. \end{aligned}$$

Lastly, in R let $\alpha' + \beta' = 4n$; so that

$$\begin{aligned} R &= \sum_n \sum_{\nu}^{\frac{4n-1}{1}} \frac{q^{2n}}{(1-q^{\nu})(1-q^{4n-\nu})} \\ &= \sum_n \sum_{\nu}^{\frac{4n-1}{1}} \frac{q^{2n}}{1-q^{4n}} \left[\frac{q^{\nu}}{1-q^{\nu}} + \frac{q^{4n-\nu}}{1-q^{4n-\nu}} + 1 \right] \\ &= 2 \sum_n \sum_{\nu}^{\frac{4n-1}{1}} \frac{q^{2n+\nu}}{(1-q^{4n})(1-q^{\nu})} + \sum_n \frac{2nq^{2n}}{1-q^{4n}}. \end{aligned}$$

Consequently

$$\begin{aligned} \frac{1}{4} \frac{\kappa^2 K^2}{\pi^2} &= P + Q - R \\ &= \sum_n \frac{nq^n}{1-q^{2n}} - \sum_n \frac{2nq^{2n}}{1-q^{4n}} = \sum \frac{q^{\nu}}{1-q^{2\nu}}, \end{aligned}$$

which is the formula (4).

Thus by a purely analytical process we deduce from an equation which exhibits the number of compositions of the double of an uneven number by the addition of two uneven squares, an equation exhibiting the number of compositions of the quadruple of an uneven number by the addition of four uneven squares. This analysis Jacobi has expressed arithmetically as follows. Representing by N an uneven number, by $[4N]$ the number of compositions of $4N$ by the addition of four uneven squares, we resolve $4N$ in every possible way into two unevenly even numbers $2N_1$ and $2N_2$, and each of these in every possible way into two uneven squares; we thus obtain the equation

$[4N] = \Sigma[2N_1 = (2x+1)^2 + (2y+1)^2] \times [2N_2 = (2x+1)^2 + (2y+1)^2]$, in which the summation extends of every pair of uneven numbers N_1 and N_2 which satisfy the equation $2N = N_1 + N_2$, and the square brackets represent the number of solutions in positive integers of the equations included in them. Observing that $[2N_1 = (2x+1)^2 + (2y+1)^2]$ is the excess of the number of divisors of N_1 which are of the form $4k+1$, above the number of its divisors which are of the form $4k-1$, retaining the signification of $\alpha, \beta, \alpha', \beta'$, and denoting by a and b any positive uneven numbers, we may transform the expression of $[4N]$ into the following,

$$[4N] = [2N = (a+b)\alpha] + [2N = a\alpha + b\beta] - [2N = a\alpha' + b\beta'],$$

in which the square brackets still retain the same signification. Supposing, as before, $\beta > \alpha$, and $\beta = \alpha + 4n$, we have

$$[2N = a\alpha + b\beta] = 2[2N = \alpha(a+b) + 4nb];$$

or, putting $\alpha = \nu + 4kn$, ν being less than $4n$,

$$[2N = a\alpha + b\beta] = 2[2N = \nu(a+b) + 4n(\overline{a+b}k + b)] = 2[N = \nu x + 2ny],$$

y being uneven and $\nu < 2n$. Again, if in $[2N = a\alpha' + b\beta']$ we write $4n$ for $\alpha' + \beta'$, and suppose $a > b$ (the supposition $a = b$ is inadmissible as it would render N even), we have

$$[2N = a\alpha' + b\beta'] = 2[N = \alpha' \frac{a-b}{2} + 2nb] = 2[N = \nu x + 2ny],$$

as before. Hence $[2N = a\alpha + b\beta] - [2N = a\alpha' + b\beta'] = 0$, and $[4N] = [2N = (a+b)\alpha]$, *i. e.* $[4N]$ is the sum of the divisors of N . In this arithmetical process we determine the coefficient of q^N in P, Q, R , instead of determining those functions themselves; and as the difference $Q - R = -\Sigma_n \frac{2nq^{2n}}{1 - q^{4n}}$ is an even function in the analytical process, so the difference $[2N = a\alpha + b\beta] - [2N = a\alpha' + b\beta']$ vanishes in the arithmetical one.

Lejeune Dirichlet, in a letter addressed to M. Liouville (*Liouville's Journal*, New Series, vol. i. p. 210), has put Jacobi's demonstration into a form in which it is more easily followed, but is a little further removed from the analysis. He shows that to every solution of the equation $a\alpha + b\beta = 2N$, in which $\alpha > \beta$, there corresponds a solution of the equation $a'\alpha' + b'\beta' = 2N$, in which $\alpha' > \beta'$, and *vice versa*, the two solutions being connected by the relation

$$\left| \begin{array}{cc} \alpha' & b' \\ \beta' & -a' \end{array} \right| = \left| \begin{array}{cc} x+1 & x+2 \\ x & x+1 \end{array} \right| \times \left| \begin{array}{cc} b & \alpha \\ a & -\beta \end{array} \right|,$$

where x is the integral number immediately inferior to $\frac{\beta}{\alpha - \beta}$, or, which is the

same thing, to $\frac{\beta'}{\alpha' - \beta'}$. Hence, as before, $[2N = a\alpha + b\beta] = [2N = a'\alpha' + b'\beta']$, and $[4N]$ is equal to the sum of the divisors of N .

128. *Theorems of Jacobi on Simultaneous Quadratic Forms.*—In an elaborate memoir "On Series whose Exponents are of two Quadratic Forms"*, Jacobi has established a great number of elliptic formulæ, which are the analytical expression of theorems relating to the representation of numbers by certain quadratic forms. A comparison of the two criteria of Gauss for the biquadratic character of 2 with respect to a prime p of the linear form $8k+1$, leads to a result which will serve as an example of these theorems. By the first criterion, 2 is or is not a biquadratic residue of a prime p of the form $8k+1$ according as a is even or uneven in the equation $p = (4a+1)^2 + 8b^2$;

* Crelle's Journal, vol. xxxvii. p. 61 and 221; or *Mathematische Werke*, vol. ii. p. 67.

by the second, 2 is or is not a biquadratic residue of p according as β is even or uneven in the equation $p = (4\alpha + 1)^2 + 16\beta^2$ *. We infer therefore that $\alpha + \beta$ is even, or (since $\alpha + b + \alpha$ is even by virtue of the congruence $(4\alpha + 1)^2 + 8b^2 \equiv (4\alpha + 1)^2, \text{ mod } 16$) that $\alpha + \beta + b$ is even. This result is thus generalized by Jacobi.

“For any number P the sum $\Sigma(-1)^b$, *i. e.*, the excess of the number of solutions of the equation $P = (4\alpha + 1)^2 + 8b^2$ in which b is even above the number of solutions in which b is uneven, is equal to the sum $\Sigma(-1)^{\alpha+\beta}$, *i. e.* to the excess of the number of solutions of the equation $P = (4\alpha + 1)^2 + 16\beta^2$, in which $\alpha + \beta$ is even above the number of solutions in which $\alpha + \beta$ is uneven.”

The generalized theorem is expressed analytically by the equation

$$\Sigma(-1)^n q^{(4m+1)^2+8n^2} = \Sigma(-1)^{m+n} q^{(4m+1)^2+16n^2}, \quad (\Sigma)$$

in which the summations extend to all values of m and n from $-\infty$ to $+\infty$. But this equation is an elliptic formula; for, on dividing by q , and writing q for q^8 , it becomes

$$\Sigma(-1)^n q^{n^2} \times \Sigma q^{2m^2+m} = \Sigma(-1)^n q^{2n^2} \Sigma(-1)^m q^{2m^2+m},$$

which is included in the equations (28) of art. 125, and is therefore a corollary from the fundamental property of the Theta functions expressed in equation (7) of art. 124. We infer at the same time, from the equations (28), that either of the sums $\Sigma(-1)^{m+n} q^{(4m+1)^2+16n^2}$ or $\Sigma(-1)^n q^{(4m+1)^2+8n^2}$ is equal to

$$\prod_{m=1}^{m=\infty} (1 - q^{8m})(1 - q^{16m}).$$

We thus arrive at an analytical proof of Jacobi's theorem, including, as a particular case, a proof of the identity of Gauss's two criteria. But the continuation of Jacobi's memoir was intended to contain direct arithmetical demonstrations (which, however, have never been published) of the theorems of which the equation $\Sigma(-1)^b = \Sigma(-1)^{\alpha+\beta}$ is an example. He says, “Though these arithmetical demonstrations of results obtained analytically present no essential difficulty, yet they are sometimes of a complicated character, and require peculiar classifications of numbers which perhaps may be of use in other researches. We have here a certain amount of freedom in the choice of methods, so that the proofs can easily be varied” †. Probably one of these methods was that employed by Dirichlet in his earliest arithmetical memoir, to which Jacobi expressly refers. In this memoir ‡ (written when only the enunciations of Gauss's criteria for the biquadratic character of 2 had been published) Dirichlet gives a demonstration of the first criterion, which

* *Theoria Residuorum Biquadraticorum*, arts. 13–21. To the second criterion we have already referred in this Report (art. 24, and in the additions to Part I., printed at the end of Part II.); the first is more elementary, and is inferred from the equation $p = (4\alpha + 1)^2 + 8b^2$, in which p is a prime of the form $8k + 1$. Raising each side of the congruence $-8b^2 \equiv$

$(4\alpha + 1)^2, \text{ mod } p$, to the power $\frac{p-1}{4}$, and observing that $2^{\frac{p-1}{2}} \equiv \left(\frac{2}{p}\right) = 1, (-1)^{\frac{p-1}{4}} = 1,$

we find $2^{\frac{p-1}{4}} \left(\frac{b}{p}\right) \equiv \left(\frac{4\alpha+1}{p}\right)$. But if $b = 2^\gamma \beta$, where β is uneven, $\left(\frac{b}{p}\right) = \left(\frac{\beta}{p}\right) = \left(\frac{p}{\beta}\right) = 1,$

because $p \equiv (4\alpha + 1)^2, \text{ mod } \beta$; and $\left(\frac{4\alpha+1}{p}\right) = \left(\frac{p}{4\alpha+1}\right) = \left(\frac{8b^2}{4\alpha+1}\right) = \left(\frac{2}{4\alpha+1}\right) = (-1)^a.$

Hence $2^{\frac{p-1}{4}} \equiv (-1)^a, \text{ mod } p$, which is Gauss's first criterion.

† *Mathematische Werke*, vol. ii. p. 73.

‡ *Crelle's Journal*, vol. iii. p. 35.

does not differ from that subsequently given by Gauss (Theor. Res. Biqu. Comm. prima, art. 13), and then deduces the second criterion, as follows, from the first. Since $p = (4a+1)^2 + 8b^2 = (4\alpha+1)^2 + 16\beta^2$, we have $[4(a+\beta)+1] \times [4(a-\beta)+1] = (4\alpha+1)^2 - 8b^2$. No common divisor of $4a+1$ and b can also be a common divisor of $4(a+\beta)+1$ and $4(a-\beta)+1$, i. e. of $4a+1$ and b ; for p is not divisible by any square. The greatest common divisor of $(4a+1)^2$ and b^2 must therefore be a product of two relatively prime uneven squares δ^2 and δ'^2 , dividing $4(a+\beta)+1$ and $4(a-\beta)+1$ respectively; $\frac{4(a+\beta)+1}{\delta^2}$

is thus a divisor of the quadratic form $x^2 - 8y^2$, in which x and y are relatively prime; it is, consequently, itself of that quadratic form, and $4(a+\beta)+1 \equiv 1, \text{ mod } 8$; this congruence implies that $a+\beta \equiv 0, \text{ mod } 2$, or, which comes to the same thing, that $b \equiv \alpha+\beta, \text{ mod } 2$. It will be seen that this demonstration of the congruence $b \equiv \alpha+\beta, \text{ mod } 2$, applies to any two representations of any number P by the forms $f = (4a+1)^2 + 8b^2$ and $\phi = (4\alpha+1)^2 + 16\beta^2$, provided that in the two representations the four numbers $4a+1, 4\alpha+1, b, \beta$ have no common divisor. To prove, for every uneven value of P , the truth of Jacobi's equation $\Sigma(-1)^a = \Sigma(-1)^{a+\beta}$, we observe, first of all, that the equation is evidently true if P is not $\equiv 1, \text{ mod } 8$, or if P contain an uneven power of a prime of the linear form $8k+7$; for in these cases there are no representations of P by either form. We may therefore suppose that P is of the linear form $8k+1$; then the equation is true if P contains an uneven power of any prime p of either of the linear forms $8k \pm 3$; thus if $P = p^{2\nu+1}P'$, where P' is prime to p , and $p \equiv P' \equiv 3, \text{ mod } 8$, there are no representations of P by ϕ , so that $\Sigma(-1)^{a+\beta} = 0$; let the equations $p^{2\nu+1} = x^2 + 2y^2$, $P' = X^2 + 2Y^2$ denote generally those representations of $p^{2\nu+1}$ and P' by the form $(1, 0, 2)$, in which the first indeterminate is $\equiv 1, \text{ mod } 4$; then the representations of $P = p^{2\nu+1} \times P'$ by f will be comprised in the formula $P = (2yY - xX)^2 + 8\left(\frac{yX + xY}{2}\right)^2$ *; but of the two numbers $\frac{1}{2}(yX + xY)$,

$\frac{1}{2}(yX - xY)$ (both being values of the second indeterminate), one is uneven the other even; whence $\Sigma(-1)^b = 0 = \Sigma(-1)^{a+\beta}$. Similarly if $P = p^{2\nu+1}P'$, where P' is prime to p , and $p \equiv P' \equiv 5, \text{ mod } 8$, there are no representations of P by f , and it may be shown that $\Sigma(-1)^{a+\beta} = 0 = \Sigma(-1)^b$. We may therefore confine ourselves to the case in which P is composed of any powers of primes of the linear form $8k+1$, and of even powers of primes of the forms $8k+3, 5, 7$. If, on this supposition, $P = P' \times P''$, where P' and P'' are relatively prime, and each is $\equiv 1, \text{ mod } 8$, the sums $\Sigma(-1)^a$ and $\Sigma(-1)^{a+\beta}$, relative to P , are the products of the corresponding sums relative to P' and P'' . This may be proved by observing that the representations of P by f [or ϕ] may be obtained by compounding the representations of P' and P'' by that form, and that each representation of P has the character of an even or uneven b [or $\alpha+\beta$] according as the representations of P' and P'' of which it is compounded agree or differ in respect of that character. Thus it is sufficient to consider the four cases in which (1) $P = p^\nu$, $p \equiv 1, \text{ mod } 8$; (2) $P = p^{2\nu}$, $p \equiv 3, \text{ mod } 8$; (3) $P = p^{2\nu}$, $p \equiv 5, \text{ mod } 8$; (4) $P = p^{2\nu}$, $p \equiv 7, \text{ mod } 8$. In the last of these cases it is evident that $\Sigma(-1)^b = +1 = \Sigma(-1)^{a+\beta}$; in the others, the proof is supplied by Dirichlet's method. (i) If $P = p^\nu$, $p \equiv 1, \text{ mod } 8$, there are two primitive and $\nu-1$ derived representations of P by each form; and

* For $2yY - xX \equiv 1, \text{ mod } 4$; and the representations comprised in the formula are all different, their number being equal to the number of sets of representations of P by $(1, 0, 8)$.

the application of Dirichlet's method shows that, for *every* representation of P by ϕ , $(-1)^{a+\beta}$ has the same value as $(-1)^b$ in either *primitive* representation of P by f , and, conversely, that for *every* representation of P by f , $(-1)^b$ has the same value as $(-1)^{a+\beta}$ in either *primitive* representation of P by ϕ ; whence the units $(-1)^b$ and $(-1)^{a+\beta}$ have all the same value, and $\Sigma(-1)^b = \Sigma(-1)^{a+\beta} = \pm(\nu+1)$. The ambiguous sign is that of $(-1)^b$ in the primitive representation of P by f , and will be found (by reasoning similar to that which establishes Gauss's first criterion) to coincide with $(-1)^{\frac{1}{2}(P-1)}\epsilon^\nu$, where

ϵ is the unit satisfying the congruence $2^{\frac{p-1}{4}} \equiv \epsilon, \text{ mod } p$. (ii) If $P=p^{2\nu}$, $p \equiv 3, \text{ mod } 8$, there is but one representation of P by ϕ , and $\Sigma(-1)^{a+\beta} = (-1)^\nu$: there are $2\nu+1$ representations of P by f , of which two are primitive, $2(\nu-1)$ are derived from the primitive representations of $p^2, p^4, \dots, p^{2(\nu-1)}$, and in the remaining one $b=0$. Applying Dirichlet's method to the equation

$$q^{2\sigma} = (4\alpha+1)^2 + 8\beta^2 = (4\alpha+1)^2 + 16\beta^2$$

(in which $\sigma=1, 2, \dots, \nu$, $\beta=0$, $4\alpha+1 = (-1)^\sigma q^\sigma$, and the representation by f is primitive), we find $(-1)^b = (-1)^\sigma$; whence inasmuch as the character $(-1)^b$ is the same in a derived representation, and in the representation from

which it is derived $\Sigma(-1)^b = 1 + 2 \sum_{\sigma=1}^{\nu} (-1)^\sigma = (-1)^\nu = \Sigma(-1)^{a+\beta}$. (iii) Lastly,

if $P=p^{2\nu}$, $p \equiv 5, \text{ mod } 8$, there is but one representation by f , and $\Sigma(-1)^b = +1$; there are $2\nu+1$ representations by ϕ . Applying Dirichlet's method as in the preceding case, we find that for any primitive representation of an even power of p by ϕ , $(-1)^{a+\beta} = +1$; whence, for a derived representation in which the greatest common divisor of the indeterminates is q^σ , $(-1)^{a+\beta} = (-1)^\sigma$. Consequently $\Sigma(-1)^{a+\beta} = 2 \sum_{\sigma=1}^{\nu-1} (-1)^\sigma + (-1)^\nu = +1 = \Sigma(-1)^b$.

This completes the demonstration of Jacobi's theorem.

Let P be any uneven number and $\chi(P)$ the positive numerical transcendent defined by the equation

$$\chi^2(P) \times \psi(P) = \Sigma(-1)^{\frac{d-1}{2}} \times \Sigma(-1)^{\frac{d^2-1}{8}} \times \Sigma(-1)^{\frac{d-1}{2} + \frac{d^2-1}{8}},$$

where $\psi(P)$ is the number of divisors of P , and d is any divisor of P . It will be seen that $\chi(P)=0$, except when P is capable of representation both by ϕ and f : when P is capable of such simultaneous representation, let $P=(4\alpha+1)^2+16\beta^2$ be a representation of P by ϕ in which the greatest common divisor of $4\alpha+1$ and β is the least possible; let $\varpi=4\alpha+1+4i\beta$, and let $\left[\frac{1+i}{\varpi}\right]$ represent the quadratic character (art. 27) of $1+i$ with respect to ϖ ; the equation

$$\Sigma(-1)^b = \Sigma(-1)^{a+\beta} = \left[\frac{1+i}{\varpi}\right] \chi(P)$$

will hold in each of the cases considered separately above; but the numerical functions occurring in this equation satisfy the condition $\phi(P_1) \times \phi(P_2) = \phi(P_1 P_2)$, where P_1, P_2 are relatively prime; the equation is therefore universally true for every uneven number P , and implies the identity

$$\Sigma(-1)^n q^{(4m+1)^2+8n^2} = \Sigma(-1)^{m+n} q^{(4m+1)^2+16n^2} = \Sigma\left[\frac{1+i}{\varpi}\right] \chi(P) q^P.$$

From the nature of the identity (Σ) it is evident that we may substitute any function whatever (which renders the two series convergent) for the exponential of q . Thus, for example, we find

$$\begin{aligned} \Sigma \frac{(-1)^n}{[(4m+1)^2 + 8n^2]^{1+\varepsilon}} &= \Sigma \frac{(-1)^{m+n}}{[(4m+1)^2 + 16n^2]^{1+\varepsilon}} = \Sigma \left[\frac{1+i}{\varpi} \right] \frac{\chi(P)}{P^{1+\varepsilon}} \\ &= \Pi \frac{1}{\left(1 - \frac{\eta}{p_1^{1+\varepsilon}}\right)^2} \Pi \frac{1}{1 + \frac{1}{p_2^{2(1+\varepsilon)}}} \Pi \frac{1}{1 - \frac{1}{p_3^{2(1+\varepsilon)}}}, \end{aligned}$$

where p_1, p_2, p_3 are primes of the forms $8n+1$; $8n+3$; $8n+5$ or 7 , respectively; and η is a positive or negative unit determined by the congruence

$$(-1)^{\frac{p_1-1}{8}} 2^{\frac{p_1-1}{4}} \equiv \eta, \text{ mod } p_1.$$

It would seem that the method of Dirichlet which we have here described may be employed to prove all the theorems of Jacobi's memoir in which the two forms compared have different determinants. Those in which the two forms compared have the same determinant, or determinants differing only by a square factor, are of a more elementary character, and are capable of immediate verification. But Dirichlet's method may also be extended to cases in which one or both of the forms compared has a positive determinant. One example will suffice. If $P = (2a+1)^2 + 8b^2 = (2\alpha+1)^2 - 8\beta^2$, we have

$$\Sigma (-1)^n \phi[(2m+1)^2 + 8n^2] = \Sigma (-1)^{m+n} \phi[(2m+1)^2 - 8n^2],$$

ϕ representing any function whatever which renders the series convergent, and the limits of m and n in the first sum being $0, \infty$, and $-\infty, +\infty$; in the second sum $0, \infty$, and $1, \frac{1}{3}(2m+1)$.

129. We proceed to indicate very briefly the origin of the principal formulæ in Jacobi's memoir. Three of them are distinguished from the rest as general, being deduced from the equation (7) of art. 124, without any specialization. If in that formula we write successively $+z$ and $-z$ for v , and multiply the results together, the left-hand member becomes $\Sigma (-1)^m q^{m^2+n^2} z^{m+n}$; the right-hand member may be written in the form

$$\prod_1^{\infty} (1 - q^{4m-2})^2 (1 - q^{4m}) \times \prod_1^{\infty} (1 - q^{4m})(1 - q^{4m-2}z^2)(1 - q^{4m-2}z^{-2}),$$

where the second infinite product, by the equation (7), is equal to $\Sigma (-1)^m q^{2m^2} z^{2m}$, and the first to $\Sigma (-1)^m q^{2m^2}$. Hence

$$\Sigma (-1)^m q^{m^2+n^2} z^{m+n} = \Sigma (-1)^{m+n} q^{2(m^2+n^2)} z^{2m}, \quad \dots \dots (A)$$

which is one of Jacobi's general formulæ. The other two general formulæ, and most of the special ones, are obtained in like manner by considering infinite products which are capable of being expressed in more ways than one as the product of two Theta functions. To arrive at his special formulæ, Jacobi transforms the equation (7) by writing q^a , where a is positive, for q , and $\pm q^b$ for v . He thus obtains the equations

$$\prod_1^{\infty} (1 - q^{2ma-a-b})(1 - q^{2ma-a+b})(1 - q^{2ma}) = \Sigma (-1)^m q^{am^2+mb},$$

$$\prod_1^{\infty} (1 + q^{2ma-a-b})(1 + q^{2ma-a+b})(1 - q^{2ma}) = \Sigma q^{am^2+mb}.$$

Any infinite product of either of the types occurring in these equations he calls an elliptic product; and every infinite product which can be formed in more ways than one by the multiplication of two elliptic products, leads directly to one of his special formulæ. The five following elliptic products are of great importance in the theory; they correspond to the suppositions

$$a=1, b=0; a=2, b=1; a=\frac{3}{2}, b=\frac{1}{2}.$$

$$\left. \begin{aligned} \prod_1^{\infty} (1-q^{2m-1})^2 \prod_1^{\infty} (1-q^{2m}) &= \Sigma (-1)^m q^{m^2} \\ \prod_1^{\infty} (1+q^{2m-1})^2 \prod_1^{\infty} (1-q^{2m}) &= \Sigma q^{m^2} \\ \prod_1^{\infty} (1-q^{2m-1}) \prod_1^{\infty} (1-q^{4m}) &= \Sigma (-1)^m q^{2m^2+m} \\ \prod_1^{\infty} (1+q^{2m-1}) \prod_1^{\infty} (1-q^{4m}) &= \Sigma q^{2m^2+m} \\ \prod_1^{\infty} (1-q^m) &= \Sigma (-1)^m q^{\frac{1}{2}(3m^2+m)}; \end{aligned} \right\} \dots \dots (B)$$

the first two are the equations (19) and (20) of art. 124; the last is a celebrated formula due to Euler.

The infinite products in the numerators and denominators of the fractions equal to u and u' (equations 27 and 28, art. 125) are all elliptic products of one or other of these five types, in some cases with q^2 , or q^3 , or $-q$ substituted for q . Hence a comparison of any two of the fractions equal to u or to u' gives immediately one of Jacobi's special formulæ. The demonstration of the formula (Σ) in art. 128 will serve as an example of this process.

Again, Jacobi has shown that the Eulerian product (art. 124, E.)

$$\prod_1^{\infty} (1+q^m) = \prod_1^{\infty} \frac{1}{1-q^{2m-1}},$$

which Euler had himself represented by the fraction

$$\prod_1^{\infty} \frac{1-q^{2m}}{1-q^m} = \frac{\Sigma (-1)^m q^{3m^2+m}}{\Sigma (-1)^m q^{\frac{1}{2}(3m^2+m)}}, \dots \dots (C)$$

can be represented by six other fractions of which both the numerators and denominators are elliptic products; either the numerator or denominator, or both, being of one of the types (B). Thus, for example,

$$\prod_1^{\infty} (1+q^m) = \frac{\prod_1^{\infty} (1+q^{3m-2})(1+q^{3m-1})(1-q^{3m})}{\prod_1^{\infty} (1-q^{6m-3})^2(1-q^{6m})} = \frac{\Sigma q^{\frac{1}{2}(3m^2+m)}}{\Sigma (-1)^m q^{3m^2}} \dots \dots (D)$$

Here again a comparison of any two of the seven equal fractions gives one of the special formulæ: thus writing q^{24} for q in the two fractions (C) and (D), we find

$$\Sigma(-1)^n q^{(6m+1)^2 + (6n+1)^2} = \Sigma(-1)^{m+n} q^{2(6m+1)^2 + 2(6n)^2},$$

which, however, is only a particular case of the general formula (A).

The Eulerian product is also of importance in the theory of the partition of numbers. If it be developed in a series proceeding by powers of q , the coefficient $C(m)$ of the m th power of q in the development, expresses the number of ways in which m can be composed by the addition of unequal numbers, or by the addition of equal or unequal uneven numbers. Euler observed that his fractional expression of the product furnishes a recurring formula for the calculation of $C(m)$, and the same thing is true of each of Jacobi's fractions; the simplest of the seven recurring formulæ being that arising from the fraction (D), viz.,

$$\Sigma(-1)^s C(m-3s^2) = \epsilon,$$

the summation extending to all positive or negative values of s for which $m-3s^2$ is not negative, and ϵ representing 1, or 0, according as m is or is not of the form $\frac{1}{2}(3n^2 \pm n)$.

The equation $\prod_{1}^{\infty} (1-q^m) = \sum_{-\infty}^{+\infty} (-1)^m q^{\frac{1}{2}(3m^2+m)}$ is memorable historically as

the earliest example of the introduction of a Theta function into analysis*. It expresses the theorem

"The excess of the number of ways in which a given number can be composed by the addition of an even number of unequal numbers above the number of ways in which it can be composed by the addition of an uneven number of unequal numbers is $(-1)^m$ or 0, according as the given number is, or is not, of the form $\frac{1}{2}(3m^2 \pm m)$."

Of this theorem Jacobi has given an arithmetical demonstration, reproducing Euler's proof of the analytical formula.

The logarithmic differential of $\prod_{1}^{\infty} (1-q^m)$ is $-\frac{1}{q} \sum_{1}^{\infty} \Phi(m) q^m$, where $\Phi(m)$, as

in art. 125, is the sum of the divisors of m : Euler thus obtained the equation

$$\sum_{1}^{\infty} \Phi(m) q^m \times \sum_{-\infty}^{+\infty} (-1)^m q^{\frac{1}{2}(3m^2+m)} = \frac{1}{2} \sum_{-\infty}^{+\infty} (-1)^{m+1} (3m^2+m) q^{\frac{1}{2}(3m^2+m)},$$

which supplies a recurring formula for the calculation of $\Phi(m)$, viz.,

$$\Sigma(-1)^s \Phi\left(m - \frac{3s^2+s}{2}\right) = E(m),$$

the summation extending to all positive or negative values of s for which $m - \frac{3s^2+s}{2}$ is positive, and $E(m)$ representing $(-1)^{s+1}m$, or 0, according as m is, or is not, of the form $\frac{1}{2}(3s^2 \pm s)$ †.

* In the year 1750 or 1751. Nov. Comm. Petropol. vol. iii. p. 155.

† On the equations $\prod_{1}^{\infty} (1+q^m) = \prod_{1}^{\infty} \frac{1}{1-q^{2m-1}}$, $\prod_{1}^{\infty} (1-q^m) = \sum_{-\infty}^{+\infty} (-1)^m q^{\frac{1}{2}(3m^2+m)}$, and their connexion with the partitions and divisors of numbers, see Euler, Nov. Comm. Petropol. vol. iii. p. 125, vol. v. p. 59 and p. 75; Acta Petropol. vol. iv. part 1, p. 47 and p. 56 (or Commentationes Arithmeticae Collectae, Nos. IX., XI., XVI., L.; the first memoir in vol. iv. of the Acta is omitted in the collection); Introductio in Analysin Infinitorum, part 4, cap. 16; Waring, Philosophical Transactions for 1788, p. 388; Legendre, Théorie des Nombres, ed. 3, vol. ii. p. 128; Jacobi, Fundamenta Nova, p. 185, Crelle, vol. xxxii. p. 164, vol. xxxvii. p. 67, 73 (or Mathematische Werke, vol. i. p. 345, vol. ii. p. 73, 79).

The cube of the Eulerian product is equal to the series $\frac{1}{2}\Sigma(-1)^m(2m+1)q^{\frac{1}{2}(m^2+m)}$ (art. 124, equation 22); so that

$$[\Sigma(-1)^mq^{\frac{1}{2}(3m^2+m)}]^3 = \frac{1}{2}\Sigma(-1)^m(2m+1)q^{\frac{1}{2}(m^2+m)}, \quad \dots \quad (F)$$

a result which in an earlier memoir (Crelle, vol. xxi. p. 13, or translated in Liouville, First Series, vol. vii. p. 85) Jacobi describes as "hitherto unparalleled in analysis." Writing q^{24} for q , and multiplying by q^3 , it becomes

$$\left[\Sigma_2\left(\frac{3}{a}\right)q^{a^2}\right]^3 = \Sigma_1(-1)^{\frac{b-1}{2}}bq^{3b^2},$$

the summations Σ_1 and Σ_2 extending respectively to all positive uneven numbers, and to all positive uneven numbers prime to 3. In this form it expresses the theorem

"The sum $\Sigma\left(\frac{3}{a_1a_2a_3}\right)$ extended to all compositions of any number N by the addition of three uneven squares a_1^2, a_2^2, a_3^2 , all of which are prime to 3, is $(-1)^{\frac{m-1}{2}}m$ or 0 according as N is or is not the triple of an uneven square."

Differentiating logarithmically, we find

$$\Sigma_1\Sigma_2(-1)^{\frac{b-1}{2}}\left(\frac{3}{a}\right)b(a^2-b^2)q^{a^2+3b^2}=0.$$

This equation (in which all the exponents have the same quadratic form) admits of immediate verification, elementary considerations sufficing to show

that the sum $\Sigma(-1)^{\frac{b-1}{2}}\left(\frac{3}{a}\right)b(a^2-b^2)$ extended to every solution of the equation $N=a^2+3b^2$, is zero. Jacobi thus obtains a direct arithmetical proof of the formula (F). (Crelle, vol. xxi. p. 15-18.)

The square and the cube of the Eulerian product can also each of them be represented in two different ways as the quotient of two elliptic products.

Other formulæ of Jacobi's are inferred from the fundamental equation (7) in a somewhat more complicated way. Replacing v in that equation by certain roots of unity, and multiplying two or more of the results together, Jacobi obtains products which can be expressed in more than one way by means of elliptic products; the formulæ thus deduced are remarkable chiefly because they lead to equations, not between two, but between three or more series, the exponents of which have certain quadratic forms.

Lastly, a few additional equalities are derived not from the fundamental equation, but from the modular equations of the third and seventh orders. The modular equation of the third order was brought by Legendre into the form $\sqrt{k'\lambda'} + \sqrt{k\lambda} = 1$; whence evidently $\phi^2(\omega)\phi^2(3\omega) + \psi^2(\omega)\psi^2(3\omega) = 1$; writing for the functions ϕ^2 and ψ^2 their values given by equation (14), art. 124, and changing q into q^4 , we find

$$\Sigma(1-(-1)^{m+n})q^{4(m^2+3n^2)} = 4\Sigma q^{(4m+1)^2+3(4n+1)^2}.$$

The equation of the seventh order, in the form in which it has been put by M. Gutzlaff*,

$$\sqrt[4]{k'\lambda'} + \sqrt[4]{k\lambda} = 1,$$

admits of similar treatment, and furnishes as many as seven formulæ on account of the variety of expressions which the equations (27) and (28) allow us to substitute for ϕ and ψ in the equation $\phi(\omega)\phi(7\omega) + \psi(\omega)\psi(7\omega) = 1$. It

* Crelle's Journal, vol. xii. p. 173.

is only necessary to observe that we must choose for $\phi(\omega)$ and $\psi(\omega)$, and similarly for $\phi(7\omega)$ and $\psi(7\omega)$, expressions having the same denominator.

At the beginning of his memoir Jacobi says that the formulæ to which it relates are probably finite in number. It would seem that when he expressed himself thus, he had not yet found his three general formulæ, each of which contains an infinite number of equations between series having their exponents contained in the same quadratic form. But it is certainly very unlikely that equations between series whose exponents are contained in different quadratic forms, exist for any but a few of the simplest forms, or for them in infinite number.

130. *The Formulæ of M. Kronecker.*—We now come to an important series of results, discovered within the last few years by M. Kronecker, which form a memorable accession to our knowledge of quadratic forms, and which have opened an entirely new field of arithmetical inquiry. Their demonstration requires considerations of a very complicated kind; and as they are certainly among the most interesting, so also they must be reckoned among the most abstruse of arithmetical truths. Unfortunately, in the brief notices* which M. Kronecker has given of his investigations, his methods are indicated only in a very general manner; and, notwithstanding the light which has been thrown on them in the subsequent memoirs of MM. Hermite and Joubert†, it is occasionally difficult to rediscover them. Nevertheless, as a mere enumeration of formulæ, unaccompanied by any explanation of the methods by which they have been obtained, would be of little use to the reader, we shall attempt in the next article a complete demonstration of one or two of them, which may serve as specimens of the rest.

The following (with an unimportant change in the notation) are the eight equations given by M. Kronecker (Crelle, vol. lvii. p. 248; Liouville, New Series, vol. v. p. 289).

$$\text{I. } F(2^\mu m) + 2F(2^\mu m - 1^2) + 2F(2^\mu m - 2^2) + \dots \\ = 2\Phi(m) + \Phi(2^{\mu-2}m) + \Psi(2^{\mu-2}m).$$

$$\text{II. } F(2m) + 2F(2m - 1^2) + 2F(2m - 2^2) + 2F(2m - 3^2) + \dots \\ = 2\Phi(m).$$

$$\text{III. } F(2m) - 2F(2m - 1^2) + 2F(2m - 2^2) - 2F(2m - 3^2) + \dots \\ = 0.$$

$$\text{IV. } 3G(m) + 6G(m - 1^2) + 6G(m - 2^2) + 6G(m - 3^2) + \dots \\ = \Phi(m) + 3\Psi(m).$$

$$\text{V. } 2F(m) + 4F(m - 1^2) + 4F(m - 2^2) + 4F(m - 3^2) + \dots \\ = \Phi(m) + \Psi(m).$$

* The following are the memoirs of M. Kronecker on the application of the theory of elliptic functions to quadratic forms.

(1) "Ueber elliptische Functionen und Zahlen-Theorie," Monatsberichte, Oct. 29, 1857; and translated in Liouville, New Series, vol. iii. p. 265.

(2) "Ueber die Anzahl der verschiedenen Klassen von quadratischen Formen von negativer Determinante," Crelle, vol. lvii. p. 248; and translated in Liouville, vol. v. p. 289.

(3) "Ueber eine neue Eigenschaft der quadratischen Formen von negativer Determinante," Monatsberichte, May 26, 1862.

(4) "Ueber die complexe Multiplication der elliptischer Functionen," Ibid, June 26, 1862.

(5) "Auflösung der Pellschen Gleichung mittelst elliptischer Functionen," Ibid, Jan. 22, 1863.

† M. Hermite, "Sur la théorie des équations Modulaires;" M. Joubert, "Sur la Théorie des Fonctions Elliptiques et son application a la Théorie des Nombres," already cited in the note on art. 125.

$$\text{VI. } 2F(m) - 4F(m-1^2) + 4F(m-2^2) - 4F(m-3^2) + \dots \\ = (-1)^{\frac{1}{2}(m-1)} [\Phi(m) - \Psi(m)].$$

$$\text{VII. } 2F(m) - 4F(m-4^2) + 4F(m-8^2) - 4F(m-12^2) + \dots \\ = (-1)^{\frac{1}{8}(m-7)} [\Phi'(m) - \Psi'(m)].$$

$$\text{VIII. } 4\Sigma_s (-1)^{\frac{1}{8}(m-s^2)} \left[2F\left(\frac{m-s^2}{16}\right) - 3G\left(\frac{m-s^2}{16}\right) \right] \\ = (-1)^{\frac{1}{8}(m-1)} [\Phi'(m) - \Psi'(m)].$$

In these formulæ m is any positive uneven number; in the 1st, μ is ≥ 2 ; in the 7th, m is $\equiv -1, \text{ mod } 8$; in the 8th, m is $\equiv +1, \text{ mod } 8$, and the summation extends to all values of s for which $\frac{n-s^2}{16}$ is integral and not negative; similarly, the series in the first seven formulæ are to be continued until the numbers affected with the signs F and G become negative. If n is any positive number, even or uneven, $\Phi(n)$ is the sum of the divisors of n , $\Psi(n)$ the excess of those divisors of n which surpass $\sqrt{n}$ above those divisors which are surpassed by $\sqrt{n}$; $\Phi'(m)$ is the sum $\Sigma\left(\frac{2}{d}\right)d$ extended to all the divisors of m ; $\Psi'(m)$ the excess of the sum $\Sigma\left(\frac{2}{d}\right)d$ extended to all the divisors of m which surpass $\sqrt{m}$, above the sum $\Sigma\left(\frac{2}{d}\right)d$ extended to all divisors of m which are surpassed by $\sqrt{m}$. Lastly, $F(n)$ is the number of uneven classes, $G(n)$ the whole number of classes, of forms of determinant $-n$; the classes $(1, 0, 1)$, $(1, 1, 1)$, and their derived classes, being counted as $\frac{1}{2}$ and $\frac{1}{3}$ respectively; to $F(0)$ we attribute the value 0, to $G(0)$ the value $-\frac{1}{12}$.*

The arithmetical functions $F(n)$ and $G(n)$ satisfy the equations $F(4n) = 2F(n)$; $G(4n) = F(4n) + G(n)$; $G(n) = F(n)$, if $n \equiv 1, \text{ or } 2, \text{ mod } 4$; $G(n) = 2F(n)$, if $n \equiv 7, \text{ mod } 8$; $G(n) = \frac{4}{3}F(n)$, if $n \equiv 3, \text{ mod } 8$. With the help of these relations (which may be demonstrated by elementary considerations [see art. 113 of this Report], but which may also be inferred from the theory of elliptic functions) the formulæ I.–VIII. may be transformed and combined in various ways, so as to afford new and interesting results. Of these derived formulæ M. Kronecker has given two,

$$\text{IX. } F(n) + F(n-1 \cdot 2) + F(n-2 \cdot 3) + F(n-3 \cdot 4) + \dots \\ = \frac{1}{8}\Psi(4n+1),$$

$$\text{X. } E(n) + 2E(n-1^2) + 2E(n-2^2) + 2E(n-3^2) + \dots \\ = \frac{2}{3}[2 + (-1)^n]X(n),$$

where n represents any positive integer, $X(n)$ the sum of its uneven divisors, and $E(n) = 2F(n) - G(n)$, so that $E(n)$ is a function satisfying the equations $E(4n) = E(n)$; $E(n) = 0$, if $n \equiv 7, \text{ mod } 8$; $E(n) = \frac{2}{3}F(n)$, if $n \equiv 3, \text{ mod } 8$. The first of these formulæ is obtained by subtracting VI. from V.; for $F(n-k \cdot \overline{k+1}) = \frac{1}{2}F(4n+1 - [2k+1]^2)$. The other, if n is uneven, coincides

* The right-hand members of the formulæ I.–VIII. are rendered simpler by this conventional estimation of a class of det. -1 as $\frac{1}{2}$, and of an improperly primitive class of det. -3 as $\frac{1}{3}$. We have already seen that this convention is a natural one (art. 126, note); it is, however, less easy to interpret the assumption $G(0) = -\frac{1}{12}$. M. Kronecker has given his formulæ in their complete expression when these conventional estimations are disregarded; in his subsequent notes, however, he seems to prefer the simpler form, which we have adopted in the text.

with $[V.] - \frac{1}{3}[IV.]$; and with II. if n is unevenly even. If n is the quadruple of an uneven number, its left-hand member may be written in the form

$$\left[E\left(\frac{n}{4}\right) + 2E\left(\frac{n}{4} - 1^2\right) + 2E\left(\frac{n}{4} - 2^2\right) + \dots \right] \\ + \left[\frac{4}{3}F(n-1^2) + \frac{4}{3}F(n-3^2) + \frac{4}{3}F(n-5^2) + \dots \right];$$

the sum of the first of these series is $\frac{2}{3}X\left(\frac{n}{4}\right) = \frac{2}{3}X(n)$; the second series, coinciding with $\frac{2}{3}[I.] - \frac{2}{3}[V.]$, has for its sum $\frac{4}{3}X(n)$; the two series together are therefore equal to $2X(n)$. Lastly, the formula, if true for any even number, is also true for its quadruple; for if $n \equiv 0, \text{ mod } 8$,

$$E(n) + 2E(n-1^2) + 2E(n-2^2) + \dots \\ = \left[E\left(\frac{n}{4}\right) + 2E\left(\frac{n}{4} - 1^2\right) + 2E\left(\frac{n}{4} - 2^2\right) + \dots \right] \\ + [2E(n-1^2) + 2E(n-3^2) + 2E(n-5^2) + \dots],$$

and every term of the second series is zero, because the numbers $n-1^2, n-3^2, \dots$ are all $\equiv 7, \text{ mod } 8$.

Of the preceding formulæ those which contain the functions Ψ and Ψ' , are to be regarded as of a more abstruse character than those which only contain X, Φ , and Φ' . The latter, in fact, are deducible from known theorems of arithmetic. Thus if we multiply the formula X. by 12, the right-hand member becomes $8[2 + (-1)^n]X(n)$, or the number of representations of n as a sum of four squares (see art. 127). Consequently $12E(n)$ is the number of representations of n as a sum of three squares; for, assuming that this is so for $1, 2, 3 \dots n-1$, we may infer from the formula X. that it is so for n . Thus the celebrated theorem of Gauss*, which connects the number of representations of a number n as a sum of three squares, with the number of classes of quadratic forms of det. $-n$, is contained in the formula X.; and conversely, that formula is itself deducible from the theorem of Gauss combined with the other and more elementary theorem, which connects the number of representations of n as a sum of four squares with the sum of the uneven divisors of n .

131. *Demonstration of the Formulæ of M. Kronecker.*—We shall first demonstrate the formula V. For this purpose, we consider the equation $f_s(x, 1-x)=0$, obtained by writing x for κ^2 , and $1-x$ for λ^2 in the modular equation $f_s(\kappa^2, \lambda^2)=0$ of an uneven order n (art. 125). We shall determine the order of this equation by two different methods; first, by ascertaining the dimensions of $f_1(x, 1-x)$, when x is increased without limit; secondly, by assigning its roots, and the multiplicity of each of them; a comparison of these two determinations will give the formula V.

(i.) Let $x = \varphi^s(\theta)$; then

$$f_s(x, 1-x) = \Pi \left[\psi^s(\theta) - \varphi^s\left(\frac{\gamma\theta + 2k}{\gamma'}\right) \right],$$

because (art. 125)

$$f_s(\varphi^s(\theta), \lambda^2) = \Pi \left[\lambda^2 - \varphi^s\left(\frac{\gamma\theta + 2k}{\gamma'}\right) \right] \dagger,$$

* Disq. Arith. art. 291. Legendre had discovered particular cases of the theorem by induction. Hist. de l'Ac. de Paris, 1785, p. 530 sqq. Théorie des Nombres, ed. 3, vol. i. troisième partie.

† Since $\varphi^s(\omega+2) = \varphi^s(\omega)$ (equation i. Table A), the systems of values represented by

the sign of multiplication Π extending to every system of values of γ , γ' , and k .

Let $\theta = 1 + \frac{i}{\sigma}$, σ representing a real positive quantity; we obtain

$$\varphi^s\left(1 + \frac{i}{\sigma}\right) = -\frac{\psi^s(\sigma i)}{\varphi^s(\sigma i)}; \quad \psi^s\left(1 + \frac{i}{\sigma}\right) = \frac{1}{\varphi^s(\sigma i)}$$

(Table A, vi. art. 125). Again, if δ is the greatest common divisor of $\gamma + 2k$ and γ' , and if a , b , δ' are determined by the equations

$$a = -\frac{\gamma + 2k}{\delta}, \quad b = \frac{\gamma'}{\delta}, \quad \delta' = \frac{n}{\delta},$$

while c and d are two numbers, of which d is uneven, satisfying the equation $ad - bc = 1$, we find

$$\frac{c + d \frac{\gamma\left(1 + \frac{i}{\sigma}\right) + 2k}{\gamma'}}{\gamma\left(1 + \frac{i}{\sigma}\right) + 2k} = \frac{\delta \sigma i + d\gamma}{\delta'};$$

whence (Table A, iii.)

$$\varphi^s\left(\frac{\gamma\left(1 + \frac{i}{\sigma}\right) + 2k}{\gamma'}\right) = \varphi^{-s}\left(\frac{\delta \sigma i + d\gamma}{\delta'}\right) = \varphi^{-s}\left(\frac{\delta \sigma i + 2l + 1}{\delta'}\right),$$

if $2l + 1 \equiv d\gamma \pmod{\delta'}$. If we give to γ , γ' , and k in succession all the $\Phi(n)$

systems of values of which they are susceptible, $\varphi^s\left(\frac{\gamma\left(1 + \frac{i}{\sigma}\right) + 2k}{\gamma'}\right)$ will ac-

quire in succession $\Phi(n)$ values, which (except for particular values of σ) are all different; $\varphi^{-s}\left(\frac{\delta \sigma i + 2l + 1}{\delta'}\right)$ will therefore also acquire the same number of different values; i. e. δ will represent in succession every divisor of n , and $2l + 1$ every residue of its conjugate divisor δ' . We thus obtain the equation

$$f_s(a, 1 - x) = \Pi \left[\varphi^{-s}(\sigma i) - \varphi^{-s}\left(\frac{\delta \sigma i + 2l + 1}{\delta'}\right) \right],$$

the sign of multiplication extending to every combination of the values of δ , δ' , and $2l + 1$. Now let σ increase without limit, so that $x = -\frac{\psi^s(\sigma i)}{\varphi^s(\sigma i)}$ increases

without limit, and is of the same dimensions as $\epsilon^{\sigma\pi}$ (art. 125). Observing that the factor $\varphi^{-s}(\sigma i) - \varphi^{-s}\left(\frac{\delta \sigma i + 2l + 1}{\delta'}\right)$ has a finite ratio to $\epsilon^{\sigma\pi}$, if $1 \geq \frac{\delta}{\delta'}$, and to

$\epsilon^{\frac{\delta}{\delta'}\sigma\pi}$, if $1 < \frac{\delta}{\delta'}$, we see that the product $\Pi \left[\varphi^{-s}(\sigma i) - \varphi^{-s}\left(\frac{\delta \sigma i + 2l + 1}{\delta'}\right) \right]$ has a finite ratio to $\epsilon^{[\Phi(n) + \Psi(n)]\sigma\pi}$, that is to $\left[\frac{\psi(\sigma i)}{\varphi(\sigma i)}\right]^{8\Phi(n) + 8\Psi(n)}$. Hence

$\varphi^s\left(\frac{\gamma\omega + 2k}{\gamma'}\right)$ and $\varphi^s\left(\frac{\gamma\omega + 16k}{\gamma'}\right)$ are identical, k denoting any term of a complete system of residues, mod γ' .

$$f_s(x, 1-x) \div x^{\Phi(n)+\Psi(n)}$$

is finite, when x increases without limit, or $f_s(x, 1-x)$ is of the order $\Phi(n)+\Psi(n)$.

(ii.) Neither 0 nor 1 is a root of the equation $f_s(x, 1-x)=0$; for $f_s(0, 1)=1$, $f_s(1, 0)=1$; therefore (art. 125) any one of its roots can be represented by $\phi^s(\omega)$, ω denoting an imaginary quantity, in which the coefficient of i is different from zero and positive. But if $x=\phi^s(\omega)$, $f_s(x, 1-x)=\Pi\left[\psi^s(\omega)-\phi^s\left(\frac{\gamma\omega+2k}{\gamma'}\right)\right]$; hence the supposition that $\phi^s(\omega)$ is a root of the equation $f_s(x, 1-x)=0$ implies that $\psi^s(\omega)=\phi^s\left(\frac{\gamma\omega+2k}{\gamma'}\right)$, for one system (at least) of values of γ, γ' ,

and k ; *i. e.* (art. 125) that there exists an unit matrix $\begin{vmatrix} a, b \\ c, d \end{vmatrix}$ satisfying the equation

$$\frac{\gamma\omega+2k}{\gamma'} = \frac{c+d\omega}{a+b\omega}, \quad \dots \dots \dots (A)$$

$$\text{and the congruence} \quad \begin{vmatrix} a, b \\ c, d \end{vmatrix} \equiv \begin{vmatrix} 0, 1 \\ 1, 0 \end{vmatrix}, \text{ mod } 2. \quad \dots \dots \dots (A')$$

Thus, if $\phi^s(\omega)$ is a root of $f_s(x, 1-x)=0$, ω is the root of a quadratic equation

$$2ak - c\gamma' + 2(bk - \frac{1}{2}d\gamma' + \frac{1}{2}a\gamma)\omega + b\gamma\omega^2 = 0,$$

whose extreme coefficients are both uneven, and whose determinant, if $\sigma = -bk + \frac{1}{2}(a\gamma + d\gamma')$, is $\sigma^2 - n$, a number necessarily negative, because ω is imaginary. Conversely, if ω is the root of a quadratic equation, of which the extreme coefficients are both uneven, and of which the determinant is negative and included in the formula $\sigma^2 - n$, $\phi^s(\omega)$ is a root of $f_s(x, 1-x)=0$. Or, more precisely, if ω is the root of a properly primitive quadratic equation, of which the determinant $-\Delta$ is negative and the extreme coefficients are both uneven, and if n can be represented by the form $(1, 0, \Delta)$ with a positive and uneven value of the second indeterminate, $\phi^s(\omega)$ will be a root of $f_s(x, 1-x)=0$, and the multiplicity of this root will be equal to the number of such representations of n^* . To establish this, we shall show (a) that ω

annuls as many of the factors $\psi^s(\omega) - \phi^s\left(\frac{\gamma\omega+2k}{\gamma'}\right)$ as there are representations of n ; (β) that $f_s(x, 1-x)$ is divisible by $x - \phi^s(\omega)$ as often as there are factors annulled by ω . (a) Let $A + 2B\omega + C\omega^2 = 0$ be the equation satisfied by ω , and let $n = \sigma^2 + \Delta\tau^2$; A, C , and τ being positive and uneven; the four equations

$$\left. \begin{aligned} 2ak - c\gamma' &= \tau A, & bk - \frac{1}{2}d\gamma' + \frac{1}{2}a\gamma &= \tau B, \\ b\gamma &= \tau C, & -bk + \frac{1}{2}(a\gamma + d\gamma') &= \sigma \end{aligned} \right\} \quad \dots \dots (B)$$

will supply one and only one system of values for γ, γ' , and k , and one and only one unit-matrix $\begin{vmatrix} a, b \\ c, d \end{vmatrix}$ satisfying the equation (A) and congruence (A'). For the equations $a\gamma = \tau B + \sigma$, $b\gamma = \tau C$, show that γ is the greatest common divisor of $\tau B + \sigma$ and τC ; this common divisor is a divisor of n , because

$$n = \sigma^2 + \Delta\tau^2 = (\sigma - B\tau)(\sigma + B\tau) + AC\tau^2;$$

thus a, b, γ , and $\gamma' = \frac{n}{\gamma}$ are determined. Again, the congruences

* The method by which the multiplicity of the roots of the equation $f_s(x, 1-x)=0$ is here determined is chiefly taken from M. Joubert's Memoir, "Sur la Théorie des Fonctions Elliptiques," &c., pp. 22-24.

$$\begin{aligned} 2ak &\equiv \tau A \\ 2bk &\equiv \tau B - \sigma \end{aligned} \Big] \bmod \gamma',$$

determine the value of k , because $2a$ and $2b$ have no common divisor with the modulus, while the determinant

$$2(-\tau aB + \tau bA + \sigma a) = \frac{2}{\gamma} [\sigma^2 - \tau^2 B^2 + \tau^2 AC] = 2 \frac{n}{\gamma} = 2\gamma'$$

is divisible by it; when k is determined, the equations

$$c\gamma' = 2ak - \tau A, \quad d\gamma' = 2bk - (\tau B - \sigma),$$

will supply integral values of c and d ; the matrix $\begin{vmatrix} a, b \\ c, d \end{vmatrix}$ thus obtained is an unit matrix, because

$$ad - bc = \frac{1}{n} (a\gamma \times d\gamma' - b\gamma \times c\gamma') = \frac{1}{n} [(\sigma + \tau B)(\sigma - \tau B) + \tau^2 AC] = 1; \quad .$$

it also satisfies the congruence $\begin{vmatrix} a, b \\ c, d \end{vmatrix} \equiv \begin{vmatrix} 0, 1 \\ 1, 0 \end{vmatrix} \pmod{2}$, because, from the equations (B), taken as congruences for the modulus 2, we find $b \equiv c \equiv 1 \pmod{2}$, $a \equiv d \pmod{2}$; but also $ad \equiv 0 \pmod{2}$, so that $a \equiv d \equiv 0 \pmod{2}$; lastly, the equation $\frac{\gamma\omega + 2k}{\gamma'} = \frac{c + d\omega}{a + b\omega}$ is satisfied by virtue of the first three of the equations (B). Thus to each representation of n there corresponds one, and only one evanescent factor; conversely to each evanescent factor there corresponds one, and only one representation of n . For, if ω annuls the factor $\psi^s(\omega) - \phi^s\left(\frac{\gamma\omega + 2k}{\gamma'}\right)$, the equation (A) and congruence (A') are satisfied by an unit

matrix $\begin{vmatrix} a, b \\ c, d \end{vmatrix}$, in which $b > 0$, but, even if $\Delta = -1$, by only one such matrix: so that the equations (B) determine the values of σ and τ without ambiguity. The number of factors annulled by ω is therefore equal to the number of representations of n . (β) Writing $\phi^s(\theta)$ for x , we have

$$f_s(x, 1-x) = \Pi \left[\psi^s(\theta) - \phi^s\left(\frac{\gamma\theta + 2k}{\gamma'}\right) \right] = A \Pi_1 [\phi^s(\theta) - \phi^s(\omega)],$$

where A is the coefficient of the highest power of x in $f_s(x, 1-x)$, and Π_1 extends to every root $\phi^s(\omega)$ of $f_s(x, 1-x) = 0$, each root having its proper multiplicity. M. Joubert has proved that, if $\psi^s(\theta) - \phi^s\left(\frac{\gamma\theta + 2k}{\gamma'}\right)$ vanish when

$\theta = \omega$, $\lim_{\phi^s(\theta) - \phi^s(\omega)} \frac{\psi^s(\theta) - \phi^s\left(\frac{\gamma\theta + 2k}{\gamma'}\right)}{\phi^s(\theta) - \phi^s(\omega)}$ is neither infinite nor zero. For this limit is, by the usual rule,

$$-1 - \left[\frac{\frac{d}{d\theta} \cdot \phi^s\left(\frac{\gamma\theta + 2k}{\gamma'}\right)}{\frac{d}{d\theta} \cdot \phi^s(\theta)} \right]_{\theta = \omega} = -1 - \frac{1}{nM^2},$$

where M is the multiplier appertaining to the transformation $\omega = \frac{\gamma'\Omega - 2k}{\gamma}$, since (equation 31, art. 125),

$$M^2 = \frac{1}{n} \frac{\phi^s\left(\frac{\gamma\omega + 2k}{\gamma'}\right) \psi^s\left(\frac{\gamma\omega + 2k}{\gamma'}\right)}{\phi^s(\omega) \psi^s(\omega)}$$

$$\times \left[\frac{\frac{d}{d\theta} \cdot \phi^s(\theta)}{\frac{d}{d\theta} \cdot \phi^s\left(\frac{\gamma\theta+2k}{\gamma'}\right)} \right]_{\theta=\omega} = \frac{1}{n} \left[\frac{\frac{d}{d\theta} \cdot \phi^s(\theta)}{\frac{d}{d\theta} \cdot \phi^s\left(\frac{\gamma\theta+2k}{\gamma'}\right)} \right]_{\theta=\omega}.$$

The determination of M is effected as follows: from the equation

$$\frac{\gamma\omega+2k}{\gamma'} = \frac{c+d\omega}{a+b\omega},$$

or

$$\omega = \frac{\gamma'c - 2ka + (\gamma'd - 2kb)\omega}{\gamma'a + \gamma'b\omega},$$

it appears (art. 126) that the multiplier corresponding to the compounded transformations $\begin{vmatrix} \gamma' & 0 \\ -2k & \gamma' \end{vmatrix}$ and $\begin{vmatrix} a & b \\ c & d \end{vmatrix}$, applied to ω , is $[\sigma + i\tau\sqrt{\Delta}]^{-1}$; while that corresponding to the second of these transformations is simply $(-1)^{\frac{b-1}{2}}i$ (Table A, ii.); therefore $\frac{1}{M^2} = -(\sigma + i\tau\sqrt{\Delta})^2$, and the limit above written

becomes $-1 + \frac{\sigma + i\tau\sqrt{\Delta}}{\sigma - i\tau\sqrt{\Delta}}$, which is certainly neither infinite nor zero. Hence

$f_s(x, 1-x)$ is divisible by $x - \phi^s(\omega)$ precisely as often as there are factors $\psi^s(\theta) - \phi^s\left(\frac{\gamma\theta+2k}{\gamma'}\right)$ which vanish when $\theta = \omega$; i. e. the multiplicity of the root $x = \phi^s(\omega)$ in $f_s(x, 1-x) = 0$ is precisely equal to the number of solutions of the equation $n = \sigma^2 + \Delta\tau^2$, τ being positive and uneven. It remains to assign all the values of ω , which, annulling one or more of the factors $\psi^s(\theta) - \phi^s\left(\frac{\gamma\theta+2k}{\gamma'}\right)$, give different values to $\phi^s(\omega)$. It is evident that values of ω , arising from equations associated to properly primitive forms of different determinants, or of the same determinant and different classes, give different values to $\phi^s(\omega)$; again, of the six subclasses, contained in any one class, the extreme coefficients are uneven in only two; so that from each class we obtain two and only two values of $\phi^s(\omega)$. In the particular case in which the determinant is -1 , there are but three subclasses, and but one subclass in which the extreme coefficients are uneven; so that to such a class there corresponds but one value of $\phi^s(\omega)$. Denoting then by $h(\Delta)$ the number of properly primitive classes of determinant $-\Delta$ (we count $\frac{1}{2}$ instead of 1 for a class of determinant -1), and by (n, Δ) the number of solutions of the equation $n = \sigma^2 + \Delta\tau^2$, in which τ is positive and uneven, we have, for the number of unequal roots of $f_s(x, 1-x) = 0$, the expression

$$2\Sigma h(\Delta),$$

and for the whole number of its roots, when each root is reckoned with its proper multiplicity,

$$2\Sigma(n, \Delta)h(\Delta),$$

the summations in each case extending to every value of Δ , for which the equation $n = \sigma^2 + \Delta\tau^2$ is resolvable with an uneven value of τ .

We have now obtained the equation*

$$2\Sigma(n, \Delta)h(\Delta) = \Phi(n) + \Psi(n),$$

* M. Kronecker (Crelle, vol. lvii. p. 250) has exhibited each of the equations I.-VIII. in a similar form.

of which the left-hand member may be written in another form. Instead of counting the roots which appertain to the same value of Δ , and then summing with respect to Δ , we may count the roots which appertain to the same value of σ , and then sum with respect to σ . If $F(N)$ is the number of uneven classes (primitive or derived) of determinant $-N$ (we again count $\frac{1}{2}$ for a class of det. -1 , or for a class derived from such a class), $2F(n-\sigma^2)$ will be the number of roots appertaining to either of the values $+\sigma$ or $-\sigma$. We thus obtain, finally,

$$2F(n) + 4F(n-1^2) + 4F(n-2^2) + 4F(n-3^2) + \dots = \Phi(n) + \Psi(n),$$

which is the formula V.

132. We shall also demonstrate (but with less detail) the formula VII. Writing x for u , and $\frac{1}{x}$ for v , in the function $f(n, u, v)$, where $n \equiv -1, \text{ mod } 8$, and multiplying by $x^{\Phi(n)}$, we obtain an integral function of order $2\Phi(n)$, which we shall designate by $f(x)$. This function is not divisible by x , for $f(0)=1$; but we shall now show that it is divisible by

$$(x^8-1)^{\frac{1}{2}[\Phi(n)-\Psi(n)+\Phi'(n)-\Psi'(n)]},$$

and that the quotient is prime to x^8-1 . For this purpose we shall first determine the index λ , for which $\lim \left[\frac{f(x)}{(x-1)^\lambda}, x=1 \right]$ is finite and different from zero. Let $x = \phi\left(\frac{i}{\sigma}\right)$, so that

$$f(x) = \Pi \left[1 - \left(\frac{2}{\gamma}\right) \phi\left(\frac{i}{\sigma}\right) \phi\left(\frac{\gamma \frac{i}{\sigma} + 16k}{\gamma'}\right) \right],$$

and let the positive quantity σ increase without limit; then, ultimately,

$$\phi\left(\frac{i}{\sigma}\right) = \psi(i\sigma) = 1 - \frac{1}{8} \phi^8(i\sigma), \text{ and } 1-x = \frac{1}{8} \phi^8(i\sigma).$$

Also, if δ is the greatest common divisor of $16k$ and γ' , and if a, b, δ' are determined by the equations

$$a = -\frac{16k}{\delta}, \quad b = \frac{\gamma'}{\delta}, \quad \delta' = \frac{n}{\delta},$$

while c and d are two numbers (of which d is divisible by 2) satisfying the equation $ad-bc=1$, we find

$$\frac{c+d \frac{\gamma \frac{i}{\sigma} + 16k}{\gamma'}}{\gamma \frac{i}{\sigma} + 16k} = \frac{d\gamma + \delta i\sigma}{\delta'};$$

$$a+b \frac{\gamma \frac{i}{\sigma} + 16k}{\gamma'}$$

whence solving for $\frac{\gamma \frac{i}{\sigma} + 16k}{\gamma'}$, and applying the formula ii. of Table A,

$$\phi\left(\frac{\gamma\frac{i}{\sigma}+16k}{\gamma'}\right)=\left(\frac{2}{c}\right)\psi\left(\frac{d\gamma+\delta i\sigma}{\delta'}\right)=\left(\frac{2}{c}\right)\psi\left(\frac{\delta i\sigma+2l}{\delta'}\right),$$

if $2l \equiv d\gamma, \text{ mod } \delta'$. But $\left(\frac{2}{c}\right) = \left(\frac{2}{b}\right)$, because $bc \equiv -1, \text{ mod } 8$, and

$$\left(\frac{2}{b}\right) = \left(\frac{2}{\delta^2 b}\right) = \left(\frac{2}{\gamma'\delta}\right) = \left(\frac{2}{\gamma\delta}\right), \text{ because } \gamma\gamma' \equiv -1, \text{ mod } 8; \text{ so that}$$

$$\left(\frac{2}{\gamma}\right)\phi\left(\frac{\gamma\frac{i}{\sigma}+16k}{\gamma'}\right)=\left(\frac{2}{\delta}\right)\psi\left(\frac{\delta i\sigma+2l}{\delta'}\right)=\left(\frac{2}{\delta}\right)\left[1-\frac{1}{8}\phi^8\left(\frac{\delta i\sigma+2l}{\delta'}\right)\right],$$

ultimately; and

$$\lim \frac{f(x)}{(1-x)^\lambda} = 8^\lambda \lim \frac{\prod \left[1 - \left(\frac{2}{\delta}\right) + \frac{1}{8} \left(\frac{2}{\delta}\right) \left(\phi^8(i\sigma) + \phi^8\left(\frac{\delta i\sigma+2l}{\delta'}\right)\right)\right]}{\phi^{8\lambda}(i\sigma)};$$

the sign of multiplication extending to every divisor δ of n , and to every term l of a complete system of residues of its conjugate divisor δ' . Observing that

every factor of the numerator, in which $\left(\frac{2}{\delta}\right) = -1$, is finite, and that every factor, in which $\left(\frac{2}{\delta}\right) = +1$, is evanescent, and is of the same dimensions as

$\epsilon^{-\sigma}$ or $\epsilon^{-\frac{\delta}{\delta'}\sigma}$, according as $\delta > \delta'$, or $\delta < \delta'$, we see that, in order to obtain a finite value for $\lim \frac{f(x)}{(x-1)^\lambda}$, we must take for λ twice the sum of those divisors of n

which satisfy simultaneously the equation $\left(\frac{2}{\delta}\right) = +1$, and the inequality

$\delta < \sqrt{n}$, so that we shall have

$$\lambda = \frac{1}{2}[\Phi(n) - \Psi(n) + \Phi'(n) - \Psi'(n)].$$

Further, if η is any eighth root of unity, it will be found that, when $n \equiv -1, \text{ mod } 8$, $f\left(\frac{u}{\eta}, v\eta\right) = f(u, v)$, whence $f\left(\frac{x}{\eta}\right) = f(x)$, or $f(x)$ contains only powers of x having exponents divisible by 8. Consequently $f(x)$ is divisible by

$$(x^8 - 1)^{\frac{1}{2}[\Phi(n) - \Psi(n) + \Phi'(n) - \Psi'(n)]},$$

and the quotient is prime to $x^8 - 1$.

Representing, as we may now do, any root of the equation $\frac{f(x)}{(x^8 - 1)^\lambda} = 0$ by $\phi(\omega)$, we find that ω must satisfy the equation

$$\frac{1}{\phi(\omega)} = \left(\frac{2}{\gamma}\right)\phi\left(\frac{\gamma\omega+16k}{\gamma'}\right),$$

for one system at least of values of γ, γ' , and k ; that is (Table A, iii. art. 125), ω satisfies a quadratic equation of the form

$$\frac{c+d\omega}{a+b\omega} = \frac{\gamma\omega+16k}{\gamma'},$$

or

$$16ak - \gamma'c + (a\gamma' - d\gamma' + 16kb)\omega + b\gamma\omega^2 = 0,$$

where $\begin{vmatrix} a, b \\ c, d \end{vmatrix} \equiv \begin{vmatrix} 1, 1 \\ 0, 1 \end{vmatrix}, \text{ mod } 2$; $c \equiv 0, \text{ mod } 8$; $(-1)^{\frac{c}{8}} \left(\frac{2}{d}\right) = \left(\frac{2}{\gamma}\right)$. The determinant of this equation, if $\sigma = \frac{1}{2}(a\gamma + d\gamma') - 8kb$, is $\sigma^2 - n$. For brevity, let us suppose that $n \equiv -1, \text{ mod } 16$; we shall now prove that in this case $\sigma \equiv 0, \text{ mod } 8$. Since $ad \equiv 1, \text{ mod } 8$, it follows that $a \equiv d, \text{ mod } 8$; let $a = 8\alpha + \mu, d = 8\delta + \mu$; substituting these values in the equation $ad - bc = 1$, considered as a congruence for the modulus 16, we infer that $8(\alpha + \delta) \equiv c + \mu^2 - 1, \text{ mod } 16$. Again, since $\gamma\gamma' \equiv -1, \text{ mod } 8$, let $\gamma = 8\theta + \nu, \gamma' = 8\theta' - \nu$; substituting these values in the congruence $\gamma\gamma' \equiv -1, \text{ mod } 16$, we find $8(\theta + \theta') \equiv \nu^2 - 1, \text{ mod } 16$. But $2\sigma \equiv a\gamma + d\gamma' \equiv 8[\alpha + \delta + \theta + \theta'] \equiv c + \mu^2 - 1 + \nu^2 - 1 \equiv 0, \text{ mod } 16$, because $(-1)^{\frac{c}{8} + \frac{\mu^2 - 1}{8} + \frac{\nu^2 - 1}{8}} = (-1)^{\frac{c}{8}} \left(\frac{2}{d}\right) \left(\frac{2}{\gamma}\right)$

$= 1$. Therefore σ is divisible by 8, and the quantity ω is the root of an equation $A + 2B\omega + C\omega^2 = 0$, in which A is even, C uneven, and of which the determinant is included in the series of negative numbers, $-n, -n + 8^2, -n + 16^2, \dots$. An application (which we need not here repeat) of the method already employed to prove the formula V. will show that every quadratic equation satisfying these conditions supplies a value of $\phi(\omega)$. Sixteen different values of $\phi(\omega)$ will be obtained from the quadratic equations associated to the forms of any uneven class of a determinant included in the above series; because the conditions with respect to the extreme coefficients are satisfied in only two of the six subclasses contained in each class, and because each of these two subclasses supplies (art. 126) eight values of $\phi(\omega)$. Lastly, the multiplicity of the root $\phi(\omega)$ of the equation $\frac{f(x)}{(x^3 - 1)^\lambda} = 0$ is ascertained, by an ap-

plication of the method of M. Joubert (which also we need not here repeat), to be equal to the number of factors $1 - \left(\frac{2}{\gamma}\right)\phi(\omega)\phi\left(\frac{\gamma\omega + 16k}{\gamma'}\right)$ which are

annulled by ω ; or, which comes to the same thing, to the number of representations of n by the form $\sigma^2 + \Delta\tau^2$, the first indeterminate being divisible by 8, the second being uneven and positive, and $-\Delta$ representing the determinant of the primitive equation by which ω is determined. Denoting by (n, Δ) the number of such representations, we have for the whole number of roots of the equation $\frac{f(x)}{(x^3 - 1)^\lambda} = 0$, each root being taken with its proper multipli-

city, the expression $16\Sigma(n, \Delta)h(\Delta)$; whence, by a transformation already employed,

$$\left. \begin{aligned} &16F(n) + 32F(n - 8^2) + 32F(n - 16^2) + \dots \\ &= 2\Phi(n) - 4[\Phi(n) - \Psi(n) + \Phi'(n) - \Psi'(n)]. \end{aligned} \right\} \dots \dots \dots (A)$$

Considering, instead of the function $f(x)$, the function $x\Phi(n)f\left(x, -\frac{1}{x}\right)$, we obtain, by reasoning precisely similar, the formula

$$\left. \begin{aligned} &32F(n - 4^2) + 32F(n - 12^2) + 32F(n - 20^2) + \dots \\ &= 2\Phi(n) - 4[\Phi(n) - \Psi(n) + \Psi'(n) - \Phi'(n)], \end{aligned} \right\} \dots \dots \dots (B)$$

whence, by subtraction,

$$\begin{aligned} &2F(n) - 4F(n - 4^2) + 4F(n - 8^2) - 4F(n - 12^2) + \dots \\ &= \Psi'(n) - \Phi'(n), \end{aligned}$$

in accordance with M. Kronecker's formula VII.

If we had supposed $n \equiv 7, \text{ mod } 16$, the left-hand members of the formulæ (A) and (B) would have been interchanged, and the right-hand member of the formula resulting from them by subtraction would consequently become $\Phi'(n) - \Psi'(n)$.

133. We shall only indicate the origin of the remaining formulæ. Of these, the formula I. requires the simultaneous consideration of the modular equations $f(2^\mu, u^2, v^3) = 0$, and $f_s(n, 1 - u^3, v^3) = 0$ (art. 125). Writing x for v^3 , and eliminating u^2 dialytically from these two equations, we obtain a resultant $R(x)$ of the order $2^{\mu+1}\Phi(n)$ in x , as appears from the theory of elimination. Writing $\phi^s(\omega)$ for x , and observing that the coefficient of the highest power of u in $f(u^2, v^3)$ is $v^{2\mu+1}$, and in $f_s(1 - u^3, v^3)$ is unity, we find

$$R(x) = [\phi^s(\omega)]^{2^\mu \Phi(n)} \Pi \left[\phi^s \left(\frac{2^\mu \omega}{1 + 2h\omega} \right) - \psi^s \left(\frac{\gamma\omega + 2k}{\gamma'} \right) \right],$$

an equation which expresses the resultant in terms of the roots of the two equations, and in which the sign of multiplication Π extends to every combination of two roots. Since all the roots of $f_s(1 - u^3, 1) = 0$ are zero, while none of the roots of $f(u^2, 1)$ are zero, no root of the equation $R(x) = 0$ is a positive unit. But the equations $f_s(1 - u^3, 0) = 0$, $f(u^2, 0) = 0$ have common roots; so that $x = 0$ is a root of $R(x) = 0$. To determine its multiplicity, write σi for ω in the expression of $R(x)$, and increase σ without limit. The quantity

$\phi^s \left(\frac{2^\mu \omega}{1 + 2\omega} \right)$ which occurs in $\Phi(n)$ of the factors of $R(x)$ is equal to

$\phi^{-8}(2^\mu \sigma i)$, and therefore increases without limit; but since $\lim [\phi^s(\sigma i)]^{2^\mu} \times \phi^{-8}(2^\mu \sigma i) = 1$, these $\Phi(n)$ factors are cancelled by the initial factor $[\phi^s(\sigma i)]^{2^\mu \Phi(n)}$. Evaluating the remaining factors by the method of art. 131,

we find that $\lim \frac{R(x)}{x^{2\Phi(2^{\mu-2}n) - 2\Psi(2^{\mu-2}n)}}$ is finite when x diminishes without

limit; so that the order of $R(x)$, after division by the highest power of x contained in it, is $2^{\mu+1}\Phi(n) - 2\Phi(2^{\mu-2}n) + 2\Psi(2^{\mu-2}n)$, or, since $(2^{\mu-1} - 1)\Phi(n) = \Phi(2^{\mu-2}n)$, $4\Phi(n) + 2\Phi(2^{\mu-2}n) + 2\Psi(2^{\mu-2}n)$.

The formulæ II. and III. are obtained by successively combining with the equation $f_4(n, u^4, v^4) = 0$ (art. 125), the equations

$$v^4 u^4 + v^4 + u^4 - 1 = 0, \text{ and } v^4 u^4 - v^4 + u^4 + 1 = 0,$$

the first of which is equivalent to the system $v^4 = \phi^4(\omega)$, $u^4 = \psi^4 \left(\frac{\omega}{2} \right)$; the

second to the system $v^4 = \phi^4(\omega)$, $u^4 = -\psi^4 \left(\frac{\omega}{2} \right)$. The resultant of the elimination of u^4 is, in each case, an equation of the order $2\Phi(n)$ in $x = v^4$, and is not divisible by x , $x - 1$, or $x + 1$.

The following Table indicates the highest powers of x and of the divisors of $x^3 - 1$ by which the functions specified in it are divisible.

TABLE B.

| | Function. | Order. | Extraneous factor. | Order after division. |
|------------------------|--|---------------------|--|-----------------------|
| | $f_8(x, x)$ | $\Phi(n) + \Psi(n)$ | $(x^2 - x)^{\Phi(n) - \Psi(n)}$ | $3\Psi(n) - \Phi(n)$ |
| | $f_8(x, 1-x)$ | $\Phi(n) + \Psi(n)$ | | $\Phi(n) + \Psi(n)$ |
| | $x^{\Phi(n)} f_8\left(x, \frac{1}{x}\right)$ | $2\Phi(n)$ | $(x-1)^{\Phi(n) - \Psi(n)}$ | $\Phi(n) + \Psi(n)$ |
| | $(1-x)^{\Phi(n)} f_8\left(x, \frac{1}{1-x}\right)$ | $2\Phi(n)$ | | $2\Phi(n)$ |
| | $(x-1)^{\Phi(n)} f_8\left(x, \frac{x}{x-1}\right)$ | $2\Phi(n)$ | $x^{\Phi(n) - \Psi(n)}$ | $\Phi(n) + \Psi(n)$ |
| | $x^{\Phi(n)} f_8\left(x, \frac{x-1}{x}\right)$ | $2\Phi(n)$ | | $2\Phi(n)$ |
| | $x^{\Phi(n)} f_4\left(x, \frac{1}{x}\right)$ | $2\Phi(n)$ | $(x^2 - 1)^{\Phi(n) - \Psi(n)}$ | $2\Psi(n)$ |
| | $x^{\Phi(n)} f_4\left(x, -\frac{1}{x}\right)$ | $2\Phi(n)$ | | $2\Phi(n)$ |
| $n \equiv 3 \pmod{4}$ | $x^{\Phi(n)} f_2\left(x, \frac{1}{x}\right)$ | $2\Phi(n)$ | $(x^4 - 1)^{\Phi(n) - \Psi(n)}$ | $4\Psi(n) - 2\Phi(n)$ |
| $n \equiv 3 \pmod{4}$ | $x^{\Phi(n)} f_2\left(x, -\frac{1}{x}\right)$ | $2\Phi(n)$ | | $2\Phi(n)$ |
| $n \equiv 1 \pmod{4}$ | $x^{\Phi(n)} f_2\left(x, \frac{1}{x}\right)$ | $2\Phi(n)$ | $(x^2 - 1)^{\Phi(n) - \Psi(n)}$ | $2\Psi(n)$ |
| $n \equiv 1 \pmod{4}$ | $x^{\Phi(n)} f_2\left(x, -\frac{1}{x}\right)$ | $2\Phi(n)$ | $(x^2 + 1)^{\Phi(n) - \Psi(n)}$ | $2\Psi(n)$ |
| $n \equiv -1 \pmod{8}$ | $x^{\Phi(n)} f\left(x, \frac{1}{x}\right)$ | $2\Phi(n)$ | $(x^8 - 1)^{\frac{1}{2}[\Phi(n) - \Psi(n) + \Phi'(n) - \Psi'(n)]}$ | |
| $n \equiv -1 \pmod{8}$ | $x^{\Phi(n)} f\left(x, -\frac{1}{x}\right)$ | $2\Phi(n)$ | $(x^8 - 1)^{\frac{1}{2}[\Phi(n) - \Psi(n) - \Phi'(n) + \Psi'(n)]}$ | |
| $n \equiv 1 \pmod{8}$ | $f(x, x)$ | $\Phi(n) + \Psi(n)$ | $x^{\Phi(n) - \Psi(n)} (x^8 - 1)^{\frac{1}{2}[\Phi(n) - \Psi(n) + \Phi'(n) - \Psi'(n)]}$ | |
| $n \equiv 1 \pmod{8}$ | $f(x, -x)$ | $\Phi(n) + \Psi(n)$ | $x^{\Phi(n) - \Psi(n)} (x^8 - 1)^{\frac{1}{2}[\Phi(n) - \Psi(n) + \Phi'(n) - \Psi'(n)]}$ | |

The formulæ in this Table relating to $f_s(x, x)$, $f(x, x)$, and $f(x, -x)$ require a certain modification, when n is a perfect square*. If, on this hypothesis, we represent by $f_s(x, x)$ the function obtained by writing $x=v^s=u^s$ in $\frac{f_s(u^s, v^s)}{v^s-u^s}$, $f_s(x, x)$ is of the order $\Phi(n)+\Psi(n)-1$, and is divisible by $(x^2-x)^{\Phi(n)-\Psi(n)-1}$. Again, if $n=v^2$ and $\left(\frac{2}{v}\right)=1$, we represent $\lim_{v \rightarrow u} \frac{f(u, v)}{v-u}$ [$u=v=x$] by $f(x, x)$; this function is of the order $\Phi(n)+\Psi(n)-1$, and is divisible by $x^{\Phi(n)+\Psi(n)-1} \times (x^s-1)^{\frac{1}{2}[\Phi(n)-\Psi(n)+\Phi'(n)-\Psi'(n)]-1}$; if $\left(\frac{2}{v}\right)=-1$, we represent $\lim_{v \rightarrow u} \frac{f(u, -v)}{v-u}$ [$u=v=x$] by $f(x, -x)$, and this function is of the order $\Phi(n)+\Psi(n)-1$, and is divisible by

$$x^{\Phi(n)+\Psi(n)-1} \times (x^s-1)^{\frac{1}{2}[\Phi(n)-\Psi(n)+\Phi'(n)-\Psi'(n)]-1}.$$

The formula IV. may be deduced from the equation

$$f_s(x, x) \times f_s(x, 1-x) \times x^{\Phi(n)} f_s\left(x, \frac{1}{x}\right) \times (1-x)^{\Phi(n)} f_s\left(x, -\frac{x}{1-x}\right) = 0,$$

of which the order (after division by powers of x and $x-1$) is shown by the Table to be $2\Phi(n)+6\Psi(n)$.

In proving the formula V., we might have employed the equation $x^{\Phi(n)} f_s\left(x, \frac{1}{x}\right) = 0$ instead of $f_s(x, 1-x) = 0$. If, instead of the former equation,

we employ the two $x^{\Phi(n)} f_4\left(x, \frac{1}{x}\right) = 0$, $x^{\Phi(n)} f_4\left(x, -\frac{1}{x}\right) = 0$, we obtain the formulæ V. and VI. simultaneously.

Lastly, the formula VIII. depends on the equations $f(x, x) = 0$, and $f(x, -x) = 0$.

134. *Connexion of the formulæ of M. Kronecker with Elliptic series.*—*Researches of M. Hermite.*—M. Kronecker has given a remarkable analytical expression of the formulæ IX. and X. (art. 130). He employs the identical equations

$$\begin{aligned} \sum_1^{\infty} [2+(-1)^n] X(n) q^n &= \sum_1^{\infty} \frac{q^n}{[1+(-1)^n q^n]^2}, \\ \frac{1}{4} \sum_1^{\infty} \Psi(4n+1) q^{\frac{4n+1}{4}} &= q^{\frac{1}{4}} \sum_1^{\infty} \frac{q^{n^2+n-1}}{(1-q^{2n-1})^2}, \\ (1+2q+2q^4+2q^9+\dots) &\times \sum_0^{\infty} E(n) q^n \\ &= \sum_0^{\infty} [E(n)+2E(n-1^2)+2E(n-2^2)+\dots] q^n, \\ (2q^{\frac{1}{4}}+2q^{\frac{9}{4}}+2q^{\frac{25}{4}}+\dots) &\times \sum_1^{\infty} F(n) q^n \\ &= 2q^{\frac{1}{4}} \sum_1^{\infty} [F(n)+F(n-1.2)+F(n-2.3)+\dots] q^n, \end{aligned}$$

of which the first two are immediately verified by expanding their right-hand

* The necessity for a corresponding modification of the formulæ IV. and VII. is obviated by the assumption $G(0) = -\frac{1}{1^2}$.

members, the last two by multiplying together the series in their left-hand members. Combining these identities with the formulæ IX. and X., and attending to the equation $E(0) = \frac{1}{12}$, we obtain

$$\sum_{n=1}^{\infty} F(n)q^n = \frac{q^{\frac{1}{2}}}{\theta_{1,0}(0)} \sum_{n=1}^{\infty} \frac{q^{n^2+n-1}}{(1-q^{2n-1})^2}, \quad \dots \dots \dots (A)$$

$$12 \sum_{n=0}^{\infty} E(n)q^n = \frac{1}{\theta_{0,0}(0)} \left[1 + 8 \sum_{n=1}^{\infty} \frac{q^n}{[1 + (-1)^n q^n]^2} \right]; \quad \dots \dots (B)$$

of which the second (art. 127, equation 3) may be written in the form

$$12 \sum_{n=0}^{\infty} E(n)q^n = (1 + 2q + 2q^4 + 2q^9 + \dots)^3, \quad \dots \dots \dots (B')$$

in which it expresses the arithmetical theorem of Gauss, to which we have already referred (art. 130).

It appears from the equations (A) and (B) that the generating functions of $F(n)$ and $E(n)$ are elliptic series; and M. Hermite, in two important memoirs (*Comptes Rendus*, Aug. 5, 1861, or *Liouville*, New Series, vol. vii. p. 25, and *Comptes Rendus*, July 7, 1862) suggested, as it would seem, by these equations, has succeeded in deducing the second of them, and others of the same character, from the general expansions of elliptic functions, without having occasion to consider the special modules which admit of complex multiplication. He has thus discovered a new and comparatively elementary method of arriving at the formulæ of M. Kronecker; to whom indeed this method was already known, as his expressions of the generating functions of $E(n)$ and $F(n)$ indicate, and as he has himself expressly stated in a note published after the appearance of M. Hermite's first memoir (*Monatsberichte*, May 26, 1862, pp. 307, 308). M. Hermite's method is an extension of that employed by Jacobi (see art. 127), and depends on the developments of doubly periodic functions in series proceeding by sines or cosines of the multiples of the argument. To this set of developments, however, M. Hermite adds a second obtained by dividing the product of two Theta functions by a third. A series of the first set, and one of the second (both alike containing only sines, or only cosines, and only even, or only uneven multiples of the argument), are then multiplied together. The non-periodic part of the product (or its integral, taken from the limit 0 to π) is a function of q only, and if the product can be formed in more than one way, we obtain different expressions of this function, a comparison of which supplies in each case an arithmetical formula. We take the following example from M. Hermite's first memoir; and, with him, we write for brevity, Θ , Θ_1 , H , H_1 for $\Theta\left(\frac{2Kx}{\pi}\right)$, $\Theta_1\left(\frac{2Kx}{\pi}\right)$, $H\left(\frac{2Kx}{\pi}\right)$, $H_1\left(\frac{2Kx}{\pi}\right)$, and θ , θ_1 , η_1 for $\Theta(0)$, $\Theta_1(0)$, $H_1(0)^*$.

Multiplying together the three pairs of series

$$\left. \begin{aligned} \eta_1^2 \theta_1^2 \Theta^2 &= 8 \sum_{n=1}^{\infty} \frac{nq^n}{1-q^{2n}} - 8 \sum_{n=1}^{\infty} \frac{nq^n \cos 2nx}{1-q^{2n}} \\ &+ \sum_{n=-\infty}^{+\infty} q^{n^2} \cos 2nx, \end{aligned} \right\} \dots \dots \dots (i)$$

* The developments of elliptic functions, in series proceeding by sines or cosines of the multiples of the argument, which are employed in this article, will be found in the *Fundamenta Nova* (sections 40-42), or in M. Hermite's second memoir (*Comptes Rendus*, July 7, 1862).

$$\left. \begin{aligned}
 \eta_1 \theta_1^2 \frac{H\Theta_1}{\Theta^2} &= 4 \sum_0^{\infty} \frac{(2n+1)q^{\frac{2n+1}{2}}}{1+q^{2n+1}} \sin(2n+1)x, \\
 H &= 2 \sum_0^{\infty} (-1)^n q^{\frac{1}{4}(2n+1)^2} \sin(2n+1)x, \\
 \eta_1 \theta_1 \frac{H}{\Theta} &= 4 \sum_0^{\infty} \frac{q^{\frac{2n+1}{2}}}{1-q^{2n+1}} \sin(2n+1)x, \\
 \theta_1 \frac{H\Theta_1}{\Theta} &= 2 \sum_0^{\infty} Q_n q^{\frac{1}{4}(2n+1)^2} \sin(2n+1)x
 \end{aligned} \right\} \dots \dots \dots (ii)$$

$$\left. \begin{aligned}
 \text{where } Q_n &= 1 + 2q^{-1} + 2q^{-4} + \dots + 2q^{-n^2};
 \end{aligned} \right\} \dots \dots \dots (iii)$$

and designating the definite integral $\eta_1 \theta_1^2 \int_0^\pi \frac{H^2 \Theta_1}{\Theta^2} d\omega$ by πJ , we obtain

$$\begin{aligned}
 \eta_1 J &= 8 \sum_1^{\infty} \frac{nq^n}{1-q^{2n}} - 8 \sum_1^{\infty} \frac{nq^{n^2+n}}{1-q^{2n}}, \\
 \theta J &= 4 \sum_0^{\infty} (-1)^n \frac{(2n+1)q^{\frac{1}{4}(2n+1)(2n+3)}}{1+q^{2n+1}}, \\
 J &= 4 \sum_0^{\infty} Q_n \frac{q^{\frac{1}{4}(2n+1)(2n+3)}}{1-q^{2n+1}}.
 \end{aligned}$$

Let $\Delta(n)$ represent the sum of those divisors of n whose conjugates are uneven, and $\Gamma_1(n)$ the sum of those divisors of n which do not surpass $\sqrt{n}$, and which are even or uneven, according as their conjugate divisors are uneven or even; we find immediately

$$\eta_1 J = 8 \sum_1^{\infty} [\Delta(n) - \Gamma_1(n)] q^n;$$

also

$$\begin{aligned}
 \theta J &= 2 \sum_0^{\infty} (-1)^n [\Phi(4n+3) - \Psi(4n+3)] q^{\frac{4n+3}{4}}, \\
 J &= 4 \sum_0^{\infty} \sum_{\mu}^n \sum_s^{\infty} q^{\frac{1}{4}[(2n+1)(2n+4s+3) - 4\mu^2]} \\
 &= 4 \sum_0^{\infty} F'(4n+3) q^{\frac{4n+3}{4}},
 \end{aligned}$$

if $F'(4n+3)$ represent the number of solutions of the equation $4n+3=ac-b^2$, in which a and c are positive and uneven, a is less than c , b is even, and less in absolute magnitude than a . But M. Hermite has shown that $F'(4n+3)=F(4n+3)$. For $F'(4n+3)$ is evidently the number of quadratic forms (a, b, c) of determinant $-(4n+3)$, in which the second coefficient is even, and less than either extreme coefficient, and in which also the first coefficient is less than the third. But each uneven reduced form is equivalent to one, and only to one, of the forms (a, b, c) . For the reducing trans-

formation of a form (a, b, c) is necessarily one of the five following:—

$$\begin{vmatrix} 1, 0 \\ 0, 1 \end{vmatrix}, \begin{vmatrix} 1, \pm 1 \\ 0, 1 \end{vmatrix}, \begin{vmatrix} \pm 1, 1 \\ -1, 0 \end{vmatrix};$$

therefore, conversely, a reduced form can be transformed into a form (a, b, c) only by one or more of the transformations,

$$\begin{vmatrix} 1, 0 \\ 0, 1 \end{vmatrix}, \begin{vmatrix} 1, \mp 1 \\ 0, 1 \end{vmatrix}, \begin{vmatrix} 0, -1 \\ 1, \pm 1 \end{vmatrix};$$

and upon trial it will be found that there is always one, and only one among them which applied to a reduced form, produces a form (a, b, c) . The number of forms (a, b, c) is therefore equal to the number of reduced forms of determinant $-(4n+3)$; *i. e.* $F'(4n+3)=F(4n+3)$. Eliminating J , we obtain the first and third formulæ of M. Hermite's memoir,

$$\sum_0^{\infty} F(4n+3)q^{\frac{4n+3}{4}} = 2 \sum_1^{\infty} [\Delta(n) - \Gamma_1(n)] q^n,$$

$$\sum_0^{\infty} F(4n+3)q^{\frac{4n+3}{4}} = \frac{1}{2} \sum_0^{\infty} (-1)^n [\Phi(4n+3) - \Psi(4n+3)] q^{\frac{4n+3}{4}},$$

or, equating coefficients,

$$\begin{aligned} F(4n-1^2) + F(4n-3^2) + F(4n-5^2) + \dots &= \Delta(n) - \Gamma_1(n), \\ F(4n+3) - 2F(4n+3-2^2) + 2F(4n+3-4^2) - \dots &= (-1)^{\frac{n-1}{2}} [\Phi(4n+3) - \Psi(4n+3)]. \end{aligned}$$

In his second memoir M. Hermite occupies himself with the demonstration of the equation (B'). Multiplying together the two series,

$$\begin{aligned} \theta_1^2 \frac{\Theta H_1}{\Theta_1 H} &= \cot x - \sum_1^{\infty} (-1)^n \frac{4q^n \sin 2nx}{1 + (-1)^n q^n}, \\ \theta_1 \frac{H \Theta_1}{H_1} &= \tan x + 2 \sum_1^{\infty} (-1)^{n-1} Q_{n-1} q^{n^2} \sin 2nx, \end{aligned}$$

and employing the formulæ

$$\begin{aligned} \int_0^{\pi} \sin 2nx \cot x \, dx &= \pi, \\ \int_0^{\pi} \sin 2nx \tan x \, dx &= (-1)^{(n-1)} \pi, \end{aligned}$$

he finds

$$\begin{aligned} \theta_1^3 &= \frac{1}{\pi} \theta_1^3 \int_0^{\pi} \Theta \, dx = \frac{1}{\pi} \int_0^{\pi} \theta_1^2 \frac{\Theta H_1}{\Theta_1 H} \times \theta_1 \frac{H \Theta_1}{H_1} \, dx \\ &= 1 + 4 \sum_1^{\infty} \frac{q^n}{1 + (-1)^n q^n} - 2 \sum_1^{\infty} (-1)^n Q_{n-1} q^{n^2} \\ &\quad + 4 \sum_1^{\infty} \frac{Q_{n-1} q^{n^2+n}}{1 + (-1)^n q^n}, \end{aligned}$$

an expression which, by a detailed discussion, is shown to be equivalent to

$$\sum_0^{\infty} E(n) q^n.$$

In the note of May 26, 1862, to which we have already referred, M. Kroecker has given other examples of the use of this method. Multiplying together the three pairs of series,

$$\left. \begin{aligned} \eta_1^2 \theta_1^2 \frac{H^2}{\Theta^2} &= 8 \sum_1^{\infty} \frac{nq^n}{1-q^{2n}} - 8 \sum_1^{\infty} \frac{nq^n \cos 2nx}{1-q^{2n}}, \\ H_1 \cos x &= q^{\frac{1}{4}} + \sum_1^{\infty} [q^{\frac{1}{4}(2n-1)^2} + q^{\frac{1}{4}(2n+1)^2}] \cos 2nx, \end{aligned} \right\} \dots \dots \dots (i)$$

$$\left. \begin{aligned} \eta_1^2 \theta_1 \frac{HH_1}{\Theta^2} &= 8 \sum_1^{\infty} \frac{nq^n \sin 2nx}{1+q^{2n}}, \\ H \cos x &= \sum_1^{\infty} (-1)^n [q^{\frac{1}{4}(2n+1)^2} - q^{\frac{1}{4}(2n-1)^2}] \sin 2nx, \end{aligned} \right\} \dots \dots \dots (ii)$$

$$\left. \begin{aligned} \eta_1 \theta_1 \frac{H}{\Theta} \cos x &= 2 \sum_1^{\infty} \left[\frac{q^{\frac{2n-1}{2}}}{1-q^{2n-1}} + \frac{q^{\frac{2n+1}{2}}}{1-q^{2n+1}} \right] \sin 2nx, \\ \eta_1 \frac{HH_1}{\Theta} &= 4 \sum_1^{\infty} R_n q^{n^2} \sin 2nx, \end{aligned} \right\} \dots \dots \dots (iii)$$

where $R_n = q^{-\frac{1}{4}} + q^{-\frac{9}{4}} + q^{-\frac{25}{4}} + \dots + q^{-\frac{1}{4}(2n-1)^2}$,

and designating the definite integral $\theta_1 \eta_1 \int_0^{\pi} \frac{H^2 H_1}{\Theta^2} \cos x \, dx$ by πI , we find

$$\begin{aligned} \theta_1 I &= 4q^{\frac{1}{4}} \sum_1^{\infty} n \left[\frac{q^{n^2-n} - 2 + q^{n^2+n}}{q^n - q^{-n}} \right], \\ \theta I &= 4q^{\frac{1}{4}} \sum_1^{\infty} (-1)^n n q^{n^2} \frac{q^n - q^{-n}}{q^n + q^{-n}}, \\ I &= 4 \sum_1^{\infty} R_n q^{n^2} \left[\frac{q^{\frac{2n-1}{2}}}{1-q^{2n-1}} + \frac{q^{\frac{2n+1}{2}}}{1-q^{2n+1}} \right]. \end{aligned}$$

Let $\Gamma(n)$ represent the sum of those divisors of n which do not surpass $\sqrt{n}$, and which are even, or uneven, according as their conjugate divisors are even or uneven; and let $\Gamma'(n)$ represent the sum of the same divisors, each divisor being taken positively or negatively according as the sum of itself and its conjugate is unevenly or evenly even; if n is a perfect square, we are to replace $\sqrt{n}$ by $\frac{1}{2}\sqrt{n}$ in the sums $\Gamma(n)$ and $\Gamma'(n)$; we then obtain the expansions

$$\begin{aligned} \theta_1 I &= 8q^{\frac{1}{4}} \sum_1^{\infty} [\Delta(n) - \Gamma(n)] q^n, \quad \theta I = 8q^{\frac{1}{4}} \sum_1^{\infty} \Gamma'(n) q^n, \\ I &= 4q^{\frac{1}{4}} \sum_n \sum_{\mu} \sum_o \left[q^{\frac{1}{4}[(2n-1)(2n-1+4s+4) - (2\mu-1)^2]} + q^{\frac{1}{4}[(2n+1)(2n+1+4s) - (2\mu-1)^2]} \right] \\ &= 4q^{\frac{1}{4}} \sum_1^{\infty} F(4n) q^n = 8q^{\frac{1}{4}} \sum_1^{\infty} F(n) q^n, \end{aligned}$$

because the coefficient of q^n in the expansion of $\frac{1}{4}q^{-\frac{1}{2}}I$ is a sum containing two units for every solution of the equation $4n=ac-b^2$, in which, a, b, c being positive and uneven, $b < a < c$, and one unit for every such solution in which either $b=a < c$, or $b < a=c$; and because (by reasoning similar to that already employed in this article) it is ascertained that this sum is equal to the number of reduced forms of determinant $-4n$, i. e. to $F(4n)$. Eliminating I , we obtain, finally,

$$\theta_1 \Sigma F(n) q^n = \Sigma_{1}^{\infty} [\Delta(n) - \Gamma(n)] q^n, \quad \theta \Sigma F(n) q^n = \Sigma_{1}^{\infty} \Gamma'(n) q^n,$$

or

$$\text{XI.} \quad F(n) + 2F(n-1^2) + 2F(n-2^2) + \dots = \Delta(n) - \Gamma(n),$$

$$\text{XII.} \quad F(n) - 2F(n-1^2) + 2F(n-2^2) - \dots = \Gamma'(n).$$

These equations are equivalent to the formulæ I., II., III., V., VI. of M. Kronecker; these five, therefore (and with them, according to M. Kronecker, the remaining three, IV., VII., VIII.), are deducible by analytical transformations from the single equation

$$\frac{\theta_1 n_1^2}{8\pi q^{\frac{1}{2}}} \int_0^{\pi} \frac{H^2 H_1}{\Theta^2} \cos x \, dx = \Sigma_{1}^{\infty} F(n) q^n.$$

135. M. Kronecker asserts that the formulæ I.–VIII. are independent, i. e., that none of them can be deduced from the others by means of the elementary equations satisfied by the functions F and G ; and that all the similar relations, which are supplied by the theory of complex multiplication, may be obtained, with the help of those elementary equations, by combining the eight formulæ. And it is certain that the system of the eight formulæ does, in this sense, explicitly contain all the relations of similar form, which have been subsequently given by MM. Hermite and Joubert. Thus, many of these relations are particular cases of the formulæ XI. and XII., or of the combinations (XI.) $\pm$ (XII.) (in M. Joubert's memoir, the formulæ 1, 2, 3, those of page 28, and the first of page 29; also the first two formulæ in M. Hermite's memoir (Liouville, new series, vol. vii. p. 25) are of this kind); others, again, are immediately deducible from the two formulæ

$$4F(n) + 8F(n-4^2) + 8F(n-8^2) + \dots = \Phi(n), \quad n \equiv 3, \text{ mod } 8,$$

$$8F(n-2^2) + 8F(n-6^2) + 8F(n-10^2) + \dots = \Phi(n), \quad n \equiv 7, \text{ mod } 8,$$

combined by addition or subtraction with V., VI., and VII. But each of these two formulæ results from the combination $\frac{9}{2}(V.) + \frac{3}{2}(VI.) - 2(IV.)$, simplified by means of the elementary equations satisfied by F and G . In this way the formulæ 4–9 of M. Joubert's memoir, and the third formula in M. Hermite's memoir (Liouville, *ibid*, p. 36), may be obtained. Lastly, the equation

$$6G\left(\frac{n-1^2}{4}\right) + 6G\left(\frac{n-3^2}{4}\right) + \dots = \frac{1}{2}(3\Psi(n) - \Phi(n))$$

$$n \equiv 1, \text{ mod } 4$$

(M. Joubert, p. 30) arises from the combination (IV.) $-\frac{3}{2}(V.)$.

M. Joubert's formulæ, however, as they are given in his memoir, are not immediately comparable to those of M. Kronecker. He rejects from the modular equation of the uneven order n , the factors due to the square divisors of n (see art. 125 of this report), and, in consequence, those derived classes whose coefficients have any common divisor with n are excluded from his enumerations. At the same time, the numerical functions, depending on the

divisors of n , which occur in the right-hand members of his formulæ, are rendered somewhat more complicated than those of M. Kronecker. It is always possible to pass from one of M. Joubert's formulæ to the corresponding formula of M. Kronecker, by an elementary process, of which M. Joubert has himself given an example (at p. 25 of his memoir).

One formula, however, has been obtained by M. Hermite from his investigation of the discriminant of the modular equation, which is entirely distinct in form, and as it would seem in substance, from those of M. Kronecker. Taking a modular equation of a prime order n , M. Hermite shows that its discriminant is of the form

$$u^{n+1}(1-u^3)^{n+1}\left(\frac{2}{n}\right)\theta^2(u^3),$$

where $\theta(u)$ is a reciprocal polynomial, prime to u and to $1-u^3$, containing no equal factors, and of order $\frac{1}{3}(n^2-1)-\frac{1}{2}\left[n+\left(\frac{2}{n}\right)\right]$. From the nature of a

discriminant, if ω renders two of the quantities $\left(\frac{2}{\gamma}\right)\phi\left(\frac{\gamma\omega+16k}{\gamma'}\right)$ equal to one another, $\phi(\omega)$ is a root of the equation $\theta(u)=0$, and conversely. It is thus possible, by a method of which we have already given examples, to assign a system of quadratic equations (or quadratic forms) having integral coefficients, which shall correspond, one by one, to the roots of the equation $\theta(u)=0$. Equating the number of these quadratic forms to the index of the polynomial $\theta(u)$, M. Hermite obtains a formula which is essentially limited to the case when n is a prime, and which, translated into the notation of M. Kronecker, is as follows,

$$\begin{aligned} & 2\Sigma_1 F(\Delta) + 2\Sigma_2 F(\Delta) + 6\Sigma_3 G(\Delta) \\ &= \frac{1}{3}(n^2-1) - \frac{1}{2}\left[n + \left(\frac{2}{n}\right)\right], \end{aligned}$$

the summations $\Sigma_1, \Sigma_2, \Sigma_3$ extending respectively to all values of δ which give positive values to the numbers

$$\Delta = (8\delta - 3n)(n - 2\delta), \quad \Delta = 8\delta(n - 8\delta), \quad \Delta = \delta(n - 16\delta).$$

The difference between these series of determinants, and those which occur in M. Kronecker's formulæ, is very remarkable.

136. *Arithmetical Demonstrations of the Formulæ of M. Kronecker.*—M. Kronecker informs us that, when he had connected his formulæ, in the manner already described, with the expansions of certain elliptic functions, he directed his attention to the process (art. 127) by which Jacobi transformed the analytical proof of the 'theorem of four squares' into an arithmetical one*. Applying a similar transformation to the analytical proof of the equation of

$$\frac{\theta_1 \eta_1^2}{8\pi q^{\frac{1}{4}}} \int_0^\pi \frac{H^2 H_1}{\Theta^2} \cos x dx = \sum_{n=1}^{\infty} F(n) q^n,$$

he succeeded, after many reductions, in obtaining a purely arithmetical proof of the formulæ I. II. and V. which are included in XI. This important investigation has not yet been published: instead, M. Kronecker has given a remarkable theorem which appears (as he observes) to contain the germ of another, and very different, arithmetical demonstration of his formulæ. He has enunciated the theorem for prime numbers only, remarking, however, that it admits of extension to composite numbers also. The result is simplest in the case of a prime number p of the form $4m+3$.

* Monatsberichte for 1862, p. 307.

“Let (a, b, c) represent in succession every uneven reduced form of the determinants $-p, -p+1^2, -p+2^2, \dots$; only, if $a=c$, let the reduced form satisfy the special condition (art. 92) $b < 0$, instead of $b > 0$; the roots of the congruences

$$a\omega^2 + 2b\omega + c \equiv 0, \text{ mod } p,$$

of which roots the number is

$$F(p) + 2F(p-1^2) + 2F(p-2^2) + \dots,$$

are a complete system of residues for the modulus p .”

As it appears from the formula V. that the number of these congruence-roots is equal to p , it is only necessary to prove that they are all different; the demonstration of this very difficult point M. Kronecker has effected by showing that the contrary supposition is inconsistent with the inequalities satisfied by the coefficients of the reduced forms. A proof, independent of the formula V., that every residue of p is a root of one of the congruences, would of course supply a direct arithmetical proof of that formula, for the case in which n is a prime of the form $4m+3$.

Arithmetical demonstrations of the formulæ of M. Kronecker have also been obtained by M. Liouville. These demonstrations depend on the principles introduced by him into arithmetic in the series of memoirs “*Sur quelques formules générales qui peuvent être utiles dans la théorie des nombres*”*, and originally suggested (as he himself informs us) by Jacobi’s arithmetical proof of the theorem of four squares. M. Liouville has given, as an example of his method, a proof of the equation (XI.)–(XII.), or

$$4F(n-1^2) + 4F(n-3^2) + 4F(n-5^2) + \dots = \Delta(n) - \Gamma(n) - \Gamma'(n),$$

for the two cases in which n is unevenly, and evenly, even†. We shall confine our attention to the latter and somewhat simpler case. It requires two preliminary Lemmas, both included as very particular cases in M. Liouville’s general formulæ.

I. Let m represent a given uneven number, α a given positive exponent other than zero, $f(x)$ an even function, so that $f(x)=f(-x)$; we have the equation

$$\Sigma[f(d'-d'') - f(d'+d'')] = 2^{\alpha-1} \Sigma d[f(0) - f(2^{\alpha}d)],$$

the summations in the left and right-hand members extending respectively to all solutions of the equations

$$2^{\alpha}m = d'\delta' + d''\delta'', \quad m = d\delta,$$

the indeterminates $d', d'', \delta', \delta''$ in the first equation, and d, δ in the second, being positive and uneven, and two solutions of either equation being regarded as different, unless the indeterminates of the two solutions are the same and in the same order.

To establish this equation, we consider the system

$$\left. \begin{aligned} d'\delta' + d''\delta'' &= 2^{\alpha}m \\ d' + d'' &= 2\mu \\ \delta' - \delta'' &= 2\nu \end{aligned} \right\} \dots \dots \dots (a)$$

in which μ and ν are given positive integers. The solutions of this system are equal in number to the solutions of the system

$$\left. \begin{aligned} d'\delta' + d''\delta'' &= 2^{\alpha}m \\ d' - d'' &= -2\mu \\ \delta' + \delta'' &= 2\nu \end{aligned} \right\} \dots \dots \dots (a')$$

* Liouville’s Journal, vols. iii.–viii. (New Series.)

† Liouville, New Series, vol. vii. p. 44.

For, eliminating δ' and d'' , we find that (a) has as many solutions as $2^{a-1}m = \nu d' + \mu \delta''$ has solutions in which $d' < 2\mu$; and (a') has as many solutions as the same equation has solutions in which $\delta'' < 2\nu$: i.e. (a) has as many solutions as (a'); inasmuch as to every solution of $2^{a-1}m = \nu d' + \mu \delta''$ in which $d' < 2\mu$, but $\delta'' > 2\nu$, there corresponds a solution, in which $d' > 2\mu$, but $\delta'' < 2\nu$, and *vice versa*; for example, if $d' < 2\mu$, but $\delta'' > 2\nu$, let $2k\nu$ be the multiple of 2ν next inferior to δ'' , then

$$2^am = \nu(d' + 2k\mu) + \mu(\delta' - 2k\nu)$$

is a solution of the equation, in which $d' + 2k\mu > 2\mu$, but $\delta' - 2k\nu < 2\nu$.

Similarly it will be seen that the solutions of the systems

$$\left. \begin{aligned} d'\delta' + d''\delta'' &= 2^am \\ d' + d'' &= 2\mu \\ \delta' - \delta'' &= -2\nu \end{aligned} \right\} \dots \dots \dots (b)$$

$$\left. \begin{aligned} d'\delta' + d''\delta'' &= 2^am \\ d' - d'' &= 2\mu \\ \delta' + \delta'' &= 2\nu \end{aligned} \right\} \dots \dots \dots (b')$$

are equal in number.

Also the number of solutions of either of the systems

$$\left. \begin{aligned} d'\delta' + d''\delta'' &= 2^am \\ d' + d'' &= 2^ad \\ \delta' = \delta'' &= \delta \end{aligned} \right\} \dots \dots \dots (c)$$

$$\left. \begin{aligned} d'\delta' + d''\delta'' &= 2^am \\ d' = d'' &= \delta \\ \delta' + \delta'' &= 2^ad \end{aligned} \right\} \dots \dots \dots (c')$$

in each of which d, δ are two given conjugate divisors of m , is $2^{a-1}d$.

Let us now attribute to μ, ν, d, δ in the systems (a), (b), (c), (a'), (b'), (c'), all values, in succession, for which those systems are resolvable. We shall evidently obtain the sum $\Sigma f(d' + d'')$, which occurs in the equation to be proved, by extending the summation, first, to all solutions of the various systems (a), secondly, to all the solutions of the various systems (b), and lastly, to all solutions of the various systems (c). Similarly we shall obtain the sum $\Sigma f(d' - d'')$ by extending the summation to all solutions of the systems (a'), (b'), (c'). But the terms $f(d' + d'')$ arising from any one of the systems (a) or (b), are cancelled in the difference

$$\Sigma f(d' - d'') - \Sigma f(d' + d'')$$

by the terms $f(d' - d'')$ arising from the corresponding system (a') or (b'). That difference is, therefore, equal to the excess of $\Sigma f(d' - d'')$, extended to all solutions of the systems (c'), above $\Sigma f(d' + d'')$ extended to all solutions of the systems (c); so that, finally,

$$\Sigma [f(d' - d'') - f(d' + d'')] = 2^{a-1} \Sigma d [f(0) - f(2^ad)].$$

II. Let m be an uneven number, and $f(x)$ an uneven function; we have the equation

$$\Sigma f(d' + 2m') = \Sigma f\left(\frac{d_1 + \delta_1}{2}\right),$$

the summations in the left- and right-hand members extending respectively to all solutions of the equations

$$\begin{aligned} m &= 2m'^2 + d'\delta', \\ 2m &= m_1^2 + d_1\delta_1, \end{aligned}$$

the indeterminates $d' \delta' d_1 \delta_1 m_1$ being positive and uneven, but m' being even or uneven, positive, negative, or zero.

If we write $2m' + d' = x$, $\delta' - 2m' = y$, $2m' + d' - \delta' = z$, so that conversely $2m' = x - y - z$, $d' = y + z$, $\delta' = x - z$, the equation $m = 2m'^2 + d'\delta'$ becomes $2m = x^2 + y^2 - z^2$, the indeterminates being subject to the conditions

$$y + z > 0, z < x.$$

If in addition $z + x < 0$, the conditions are satisfied by the two solutions $[x, y, z]$, $[-x, y, z]$; which give rise, in the sum $\Sigma f(d'' + 2m')$, to two terms which cancel one another. We need only therefore consider those solutions, which satisfy the inequalities, $y + z > 0$, $x + z > 0$, $z < x$, or, which is the same thing, if $[z]$ represent the absolute value of z ,

$$y + z > 0, x > 0, [z] < x. \quad (d)$$

Again, if we write $\frac{1}{2}(d_1 + \delta_1) = x$, $m_1 = y$, $\frac{1}{2}(d_1 - \delta_1) = z$, the equation $2m = m_1^2 + d_1\delta_1$ becomes $2m = x^2 + y^2 - z^2$, the indeterminates being subject to the conditions

$$y > 0, x > 0, [z] < x. \quad (d')$$

To establish the proposed equation it is now only necessary to show that the equation $2m = x^2 + y^2 - z^2$ admits of equal numbers of solutions satisfying the inequalities (d) and (d'). But this is evident; for if $[x, y, z]$ satisfy one of the two sets of inequalities, but not both, $[x, -y, -z]$ satisfies the other, but not both.

By combining these two lemmas it may be proved that four times the number of solutions of the equation

$$2^{\alpha+1}m = m_1^2 + d_2\delta_2 + (d_2 + \delta_2)\delta_3 \quad (A)$$

(in which m is a given uneven number, and α a given exponent > 0) is $\Delta(2^{\alpha+1}m) - \Gamma(2^{\alpha+1}m) - \Gamma'(2^{\alpha+1}m)$, the indeterminates $m_1, d_2, \delta_2, \delta_3$ being all positive and uneven and $d_2 - \delta_2$ being evenly even. Representing by m' any number whatever, and by d', δ', d_3 positive uneven numbers, let us consider the two equations

$$2^{\alpha+1}m - 2d_3\delta_3 = m_1^2 + d_2\delta_2, \quad (e)$$

$$2^\alpha m - d_3\delta_3 = 2m'^2 + d'\delta', \quad (e')$$

and let $f(x)$ be an even function, so that $f(x - d_3) - f(x + d_3)$ is an uneven one, and may be used instead of $f(x)$ in the second lemma. Applying that lemma to the two equations (e) and (e'), and afterwards summing for every value of d_3 , we find

$$\begin{aligned} & \Sigma \left[f\left(\frac{d_2 + \delta_2}{2} - d_3\right) - f\left(\frac{d_2 + \delta_2}{2} + d_3\right) \right] \\ &= \Sigma [f(2m' + d' - d_3) - f(2m' + d' + d_3)], \end{aligned}$$

the summations extending to all solutions of (e) and (e') respectively. Observing that if $m' = 0$, $f(2m' + x)$ is an even function of x , and that if m' is not $= 0$, $f(-2m' + x) + f(2m' + x)$ is an even function of x , we transform the second member by the first lemma, and we obtain

$$\begin{aligned} & \Sigma \left[f\left(\frac{d_2 + \delta_2}{2} - d_3\right) - f\left(\frac{d_2 + \delta_2}{2} + d_3\right) \right] \\ &= 2^{\gamma-1} \Sigma [f(2m') - f(2^\gamma d + 2m')], \end{aligned}$$

the second summation extending to every solution of the equation

$$2^\alpha m - 2m'^2 = 2^\gamma d\delta,$$

d and δ being positive and uneven, and 2^γ representing the highest power of

2 contained in $2^{\alpha}m - 2m'^2$. Let $f(x) = 1$, if $x = 0$, but let $f(x) = 0$ for every other value of x ; the sum

$$\Sigma \left[f\left(\frac{d_2 + \delta_2}{2} - d_3\right) - f\left(\frac{d_2 + \delta_2}{2} + d_3\right) \right]$$

will then represent the number of solutions of the equation (A); the sum $2^{\gamma-1} \Sigma df(2m')$ will become $2^{\alpha-1} \Sigma d$, the summation extending to all solutions of the equation $m = d\delta$; and the sum $2^{\gamma-1} \Sigma df(2m' + 2^{\gamma}d)$ will become $\Sigma 2^{\gamma-1}d$, the summation extending to all solutions of the equation

$$2^{\alpha-1}m = 2^{\gamma-1}d(2^{\gamma-1}d + \delta).$$

Of these sums $2^{\alpha-1} \Sigma d$ is evidently $\Delta(2^{\alpha-1}m) = \frac{1}{4} \Delta(2^{\alpha+1}m)$; and $\Sigma 2^{\gamma-1}d$ is the sum of those divisors of $2^{\alpha-1}m$, which are less than $\sqrt{2^{\alpha-1}m}$, and which are not of the same parity as their conjugates, a sum which is identical with $\frac{1}{4} \Gamma(2^{\alpha+1}m) + \frac{1}{4} \Gamma'(2^{\alpha+1}m)$; as may be seen by considering separately the cases in which $\alpha = 1$, and $\alpha > 1$.

A second determination of the number of solutions of the equation (A) is obtained as follows. Write $2\theta + 1$ for $\frac{1}{2}(d_2 + \delta_2)$ and $4a$ for $d_2 - \delta_2$; it becomes

$$2^{\alpha+1}m - m_1^2 = (2\theta + 1)(2\theta + 1 + 2\delta_3) - 4a^2,$$

which is of the same form as that considered by M. Hermite (see art. 134). If then we attribute to m_1 any particular value, the number of solutions of the equation (A) is $F(2^{\alpha+1}m - m_1^2)$; its whole number of solutions is therefore

$$F(2^{\alpha+1}m - 1^2) + F(2^{\alpha+1}m - 3^2) + F(2^{\alpha+1}m - 5^2) + \dots;$$

equating this expression to that which we have already found, we obtain the formula (XI.)—(XII.).

M. Liouville tells us that, until M. Hermite's discussion of the equation

$$4n + 3 = (2\theta + 1)(2\theta + 1 + 2\delta_3) - 4a^2,$$

he had not observed that the number of solutions of the equation

$$2^{\alpha+1}m - m_1^2 = d_2\delta_2 + (d_2 + \delta_2)\delta_3, \quad d_2 \equiv \delta_2, \pmod{4},$$

is equal to the number of classes of quadratic forms of $\det. m_1^2 - 2^{\alpha+1}m$; but that with this exception all the principles of the preceding demonstration were in his possession; so that he had already arrived at formulæ identical with those of M. Kronecker, but referring to the numbers of solutions of certain indeterminate equations instead of to the numbers of quadratic forms of certain determinants. We also learn from him that formulæ exist, analogous to those of M. Kronecker, in which the series of determinants are of the type $2s^2 - n$, $3s^2 - n$, $\dots$ instead of $s^2 - n$.

137. *Equations satisfied by the Modules which admit of Complex Multiplication.*—We have already observed (art. 126) that the $6G(\Delta)$ values of $\phi^s(\omega)$, corresponding to the quadratic forms of $\det. -\Delta$, are the roots of an equation of that order, having rational coefficients. Several important properties of this equation have been indicated by M. Kronecker; but, notwithstanding their intimate connexion with the theory of quadratic forms, we can only offer an imperfect account of them.

We resume the notation of art. 131; and we shall begin by showing that if n is an uneven number, greater than 3, the values of $\phi^s(\omega)$, corresponding to the properly primitive classes of $\det. -n$, satisfy one or other of three equations, each of the order $2h(n)$, and each having rational coefficients. We have already seen in art. 131, that every value of $\phi^s(\omega)$, corresponding to a

form, of which the extreme coefficients are uneven, and of which the determinant is $\sigma^2 - n$, is a root of the equation $f_s(x, 1-x)=0$, and that this equation has no other roots. Again, if $\chi_2\left(\frac{1}{M^2}, \kappa^2\right)=0$ is the equation satisfied by the squares of the multipliers appertaining to the $\Phi(n)$ transformations of order n , the equation $\chi_2(n, x)=0$ will be satisfied by those roots of the equation $f_s(x, 1-x)=0$ which correspond to quadratic forms of det. $-n$, but not by the other roots of that equation. For, if $\phi^s(\omega)$ is a root of $f_s(x, 1-x)=0$, $\phi^s(\omega)$ is transformed into $\psi^s(\omega)$ by one of the $\Phi(n)$ transformations of order n ; and if $\phi^s(\omega)$ corresponds to a quadratic form of det. $-n$, the multiplier appertaining to this transformation is $\pm \frac{1}{\sqrt{n}}$; whereas if $\phi^s(\omega)$ corresponds to a

quadratic form of det. $-\Delta = \frac{\sigma^2 - n}{\tau^2}$, the multiplier is $\pm [\tau \sqrt{-\Delta} \pm i\sigma]^{-1}$ (see art.

131). Forming then the greatest common divisor of the two functions $f_s(x, 1-x)$ and $\chi_2(n, x)$, we obtain an equation of which the roots are, exclusively, those values of $\phi^s(\omega)$ which correspond to quadratic forms of det. $-n^*$. Let $\psi_1(n, x)$ represent this greatest common divisor, and denoting by $p_1 p_2 \dots$ the different primes, of which the squares are divisors of n , let us form the expression

$$\psi_1(n, x) = \frac{\psi_1(n, x) \times \Pi \psi_1\left(\frac{n}{p_1^2 p_2^2}, x\right) \times \dots}{\Pi \psi_1\left(\frac{n}{p_1^2}, x\right) \times \dots}.$$

If (A, B, C) symbolize a system of quadratic forms, having their extreme coefficients uneven, and representing the properly primitive classes of det. $-n$, the roots of the equation $\psi_1(n, x)=0$ are those values of $\phi^s(\omega)$ which correspond to the systems of quadratic equations

$$A + 2B\omega + C\omega^2 = 0, \quad C - 2B\omega + A\omega^2 = 0.$$

Thus the order of the equation is $2h(n)$: if $x = \phi^s(\omega)$ is a root, $1-x = \phi^s\left(-\frac{1}{\omega}\right)$ is also a root: the first coefficient is a power of 2, and the last coefficient is unity, because $\psi_1(n, x)$ divides $f_s(x, 1-x)$, of which the first and last coefficients are respectively a power of 2 and unity†. From the equation $\psi_1(n, x_1)=0$, we may deduce two others, $\psi_2(n, x_2)=0$, $\psi_3(n, x_3)=0$, by the substitutions $x_1 = \frac{1}{x_2}$, $x_2 = \frac{x_3}{x_3-1}$: these equations will have for their roots the

$4h(n)$ values of $\phi^s(\omega)$ corresponding to properly primitive forms of det. $-n$, not included in the subclasses (A, B, C), (C, $-B$, A). The roots of the equation $\psi_2(n, x)=0$ are the reciprocals of the roots of $\psi_1(n, x)=0$: its first coefficient is therefore unity and its last a power of 2; the equation $\psi_3(n, x)=0$ is a reciprocal equation, and its first and last coefficients are units.

Each of the three functions $\psi_1(n, x)$, $\psi_2(n, x)$, $\psi_3(n, x)$, can be decomposed into two factors, of the order $h(n)$, and containing no irrationality but $\sqrt{n}$.

* It is here assumed that if $\pm \frac{1}{\sqrt{n}}$ is not the multiplier appertaining to any of the transformations of order n by which x is changed into $1-x$, it is also not the multiplier appertaining to any of the $\Phi(n)$ transformations of the order n .

† The limit of $f_s(x, 1-x) \div x^{\Psi(n)+\Psi(n)}$, when x increases without limit, is $2^{4\Psi(n)}$, or $-2^{4\Psi(n)+1}$, according as n is not, or is, a perfect square.

If $n \equiv 3, \text{ mod } 4$, the value of $\frac{(-1)^{\frac{\gamma-1}{2}}}{M}$ (art. 125) corresponding to one of the two forms (A, B, C), (C, -B, A) is $+\sqrt{n}$, and that corresponding to the other $-\sqrt{n}$; if $n \equiv 1, \text{ mod } 4$, the values of $\frac{(-1)^{\frac{\gamma-1}{2}}}{M}$ corresponding to those two forms are both $+\sqrt{n}$ or both $-\sqrt{n}$, according as the generic character of the two forms is $(-1)^{\frac{f-1}{2}} = +1$, or $(-1)^{\frac{f-1}{2}} = -1$; in either case, therefore, the decomposition of $\Psi_1(n, x)$ into two factors, can be effected by comparing it with the equations $\chi_1(\sqrt{n}, x) = 0, \chi_1(-\sqrt{n}, x) = 0$, if $\chi_1\left(\frac{(-1)^{\frac{\gamma-1}{2}}}{M}, \kappa^2\right) = 0$ is the equation satisfied by the multipliers appertaining to the transformations of order n .

But M. Kronecker has shown that $\Psi_1(n, x)$ admits of a more profound decomposition, when n is a composite number. In fact, if ν is the number of the primes $p_1 p_2 p_3 \dots$ dividing n , $\Psi_1(n, x)$ can be resolved into 2^ν factors, each of the order $\frac{1}{2^\nu - 1} h(n)$, and containing no irrationalities but $\sqrt{p_1}, \sqrt{p_2}, \dots$. If $n \equiv 3, \text{ mod } 4$, the order of each factor is precisely equal to the number of classes in a properly primitive genus of det. $-n$; and the roots of each factor are the values of $\phi^s(\omega)$ corresponding to forms of a determinate genus. If $n \equiv 1, \text{ mod } 4$, instead of the equation $\Psi_1(n, x) = 0$, we consider the equation, of which the roots are the $h(n)$ quantities $x(1-x)$; this equation can, as before, be resolved into 2^ν generic factors, each corresponding to a determinate genus. In either case the factors only differ from one another in respect of the signs of the radicals $\sqrt{p_1}, \sqrt{p_2}, \dots$, and these signs are determined for each factor by the characters of the corresponding genus with respect to the primes $p_1, p_2, \dots$. For an account of the method by which this resolution into generic factors is obtained, we must refer to the original note of M. Kronecker (Monatsberichte, June 26, 1862, p. 370).

In one of Abel's memoirs (Œuvres Complètes, vol. i. p. 272) we find the theorem that the modules which admit of complex multiplication are capable of expression by radicals. At an earlier period Abel had doubted of the truth of this result, and he has given no indication of the method by which he obtained it. M. Kronecker's researches on complex multiplication were originally suggested by Abel's theorem; and they have led him to a complete demonstration of it. Let $n \equiv 3, \text{ mod } 4$, and let $\phi^s(\omega_1), \phi^s(\omega_2), \dots$ be the roots of one of the generic equations into which $\Psi_1(x, n) = 0$ is resolved, the imaginaries $\omega_1, \omega_2, \dots$ being determined by the equations

$$A_1 + 2B_1\omega_1 + C_1\omega_1^2 = 0, A_2 + 2B_2\omega_2 + C_2\omega_2^2 = 0, \dots$$

so that the forms $(A_1, B_1, C_1), (A_2, B_2, C_2)$ belong to the same genus. If the determinant $-n$ is regular (art. 117), it can be proved by the theory of composition, that it is possible so to select the representative forms $(A_1, B_1, C_1), (A_2, B_2, C_2)$ as to satisfy the equations $\omega_2 = \theta\omega_1, \omega_3 = \theta\omega_2, \dots$, θ denoting an uneven number prime to n , or indeed a prime not dividing n . We may thus represent the roots of the generic equation by the expressions $\phi^s(\omega_1), \phi^s(\theta\omega_1), \phi^s(\theta^2\omega_1), \dots$. But it can also be proved (by a comparison of the equations relating to the transformations of the orders n and θ) that

$\phi^*(\theta\omega_1) = \chi[\phi^*(\omega_1)]$, χ representing a rational and integral function of which the coefficients contain no irrationalities but i , $\sqrt{p_1}$, $\sqrt{p_2}$, ... The generic equation is therefore Abelian, and of course resolvable by radicals. If the determinant is irregular, having only one index of irregularity, the general expression of the roots of the generic equation is $\phi^*(\theta^{a_1}\theta^{a_2}\omega_1)$, and, as before, it will be found that $\phi^*(\theta_1\omega_1) = \chi_1[\phi^*(\omega_1)]$, $\phi^*(\theta_2\omega_1) = \chi_2[\phi^*(\omega_1)]$, the functions χ_1 and χ_2 still containing no irrationalities but i , $\sqrt{p_1}$, $\sqrt{p_2}$, ..., and further satisfying the equation $\chi_1[\chi_2(x)] = \chi_2[\chi_1(x)]$. The generic equation is therefore in this case also resolvable by radicals; and the same conclusion is true whatever be the order of irregularity of the determinant $-n$. If $n \equiv 1, \text{ mod } 4$, we should have to consider the generic equation of which the roots are of the form $\phi^*(\omega) \times \psi^*(\omega)$, and the demonstration of its resolvability is to be obtained in a similar manner.

We have for brevity confined ourselves to the case of properly primitive forms of an even determinant; but the values of $\phi^*(\omega)$ corresponding to the improperly primitive classes of a determinant of the form $-(4m+3)$, or to the properly primitive classes of even determinants, are also the roots of arithmetical equations possessing analogous properties. A method for the formation of these equations, different from that of M. Kronecker, and not requiring the use of the equation of the multiplier, has been given by M. Hermite (*Théorie des Equations Modulaires*, p. 44); but this method does not supply the ulterior decomposition of the equations into their generic factors.

138. *Application of the Theta Functions to the Pellian Equation.*—One more application of the Theta functions to arithmetic (inferior in importance to none that have been mentioned) has also been discovered by M. Kronecker (*Monatsberichte*, Jan. 22, 1863, p. 44). Let a, b, c, σ, τ represent real quantities, of which a and c are positive and a, b, c satisfy the inequality $ac - b^2 = \Delta > 0$, and let the positive quantity ρ be diminished without limit, the limit of the sum

$$\sum_{x=-\infty}^{x=+\infty} \sum_{y=-\infty}^{y=+\infty} \frac{e^{2\pi i(\sigma x + \tau y)}}{[ax^2 + 2bxy + cy^2]^{1+\rho}}$$

(in which, however, the value 0 is not to be attributed to x and y simultaneously) has been found by M. Kronecker to be

$$\left. \begin{aligned} & \frac{2\sigma^2\pi^2}{a} + \frac{\pi}{3\sqrt{\Delta}} \log \left[\frac{1}{4\pi^2} \theta'(0, \omega) \times \theta'(0, \omega') \right] \\ & - \frac{\pi}{\sqrt{\Delta}} \log [-\theta(\tau + \sigma\omega, \omega) \times \theta(-\tau + \sigma\omega', \omega')], \end{aligned} \right\} \dots (i)$$

where

$$\omega = \frac{-b + i\sqrt{\Delta}}{a}, \quad \omega' = \frac{b + i\sqrt{\Delta}}{a},$$

$$\theta(x, \omega) = \frac{1}{i} \theta_{1,1}(2Kx, \omega), \quad \theta'(x, \omega) = \frac{d \cdot \theta(x, \omega)}{dx},$$

$\sqrt{\Delta}$ being positive, and the logarithms real.

Again, let $a_1c_1 - b_1^2 = \Delta = ac - b^2$, $a_1b_1c_1$ being real and a_1c_1 positive; and let δ represent an evanescent quantity, we find

$$\sum \sum \frac{1 - e^{2\pi i\delta \left(x\sqrt{a+y} \frac{b}{\sqrt{a}} \right)}}{[ax^2 + 2bxy + cy^2]^{1+\rho}} = \sum \sum \frac{1 - e^{2\pi i\delta \left(x\sqrt{a_1+y} \frac{b_1}{\sqrt{a_1}} \right)}}{[a_1x^2 + 2b_1xy + c_1y^2]^{1+\rho}};$$

and hence, by the theorem of M. Kronecker,

$$\begin{aligned} & \lim \left[\sum \frac{1}{[ax^2 + 2bxy + cy^2]^{1+\varepsilon}} - \sum \frac{1}{[a_1x^2 + 2b_1xy + c_1y^2]^{1+\varepsilon}} \right] \\ &= \lim \left[\sum \frac{\epsilon^{2\pi i \delta} \left[x \sqrt{a+y} \frac{b}{\sqrt{a}} \right]}{[ax^2 + 2bxy + cy^2]^{1+\varepsilon}} - \sum \frac{\epsilon^{2\pi i \delta} \left[x \sqrt{a_1+y} \frac{b_1}{\sqrt{a_1}} \right]}{[a_1x^2 + 2b_1xy + c_1y^2]^{1+\varepsilon}} \right] \\ &= \frac{2\pi}{3\sqrt{\Delta}} \log \frac{a\sqrt{a}\theta'(0, \omega_1)\theta'(0, \omega_1')}{a_1\sqrt{a_1}\theta'(0, \omega)\theta'(0, \omega')} \dots \dots \dots (ii) \end{aligned}$$

This result M. Kronecker has applied, in the following manner, to the solution of the Pellian equation.

Let P and Q be positive integers not divisible by any square, of which P is > 1 , and let m and n represent positive integers prime to $2P$ and $2Q$ respectively, the limits of the sums

$$\sum_{m=1}^{m=\infty} \left(\frac{P}{m} \right) \frac{1}{m^{1+\varepsilon}} \text{ and } \sum_{n=1}^{n=\infty} \left(\frac{-Q}{n} \right) \frac{1}{n^{1+\varepsilon}}$$

are known from the researches of Dirichlet (Crelle, vol. xix. p. 360 and 364; or art. 101 of this Report), and are respectively

$$\frac{h(P) \log[T + U\sqrt{P}]}{2\sqrt{P}} \text{ and } \frac{\pi h(-Q)}{2\sqrt{Q}},$$

$h(P)$ and $h(-Q)$ denoting the number of properly primitive classes of the determinants P and $-Q$, and T, U being the least positive numbers which satisfy the equation $T^2 - PU^2 = 1$. Multiplying the two results together, and designating PQ by D , we find

$$\frac{\pi}{4\sqrt{D}} h(P) \cdot h(-Q) \cdot \log(T + U\sqrt{P}) = \lim \sum \left(\frac{P}{m} \right) \left(\frac{-Q}{n} \right) \frac{1}{(mn)^{1+\varepsilon}}. \quad (iii)$$

If P and Q are relatively prime, and congruous to one another, mod 4, so that D is not divisible by any square, and is $\equiv 1$, mod 4, the series

$$\frac{1}{2} \left[1 - \left(\frac{2}{R} \right) \frac{1}{2^{1+\varepsilon}} \right] \sum \left(\frac{f}{R} \right) \sum \frac{1}{(ax^2 + 2bxy + cy^2)^{1+\varepsilon}} \dots \dots (\Delta)$$

(in which $R=P$, or $R=Q$, according as $P \equiv Q \equiv 1$, mod 4, or $P \equiv Q \equiv 3$, mod 4; f or (a, b, c) denotes any one of a set of representative forms of det. $-D$; $\left(\frac{f}{R} \right)$ is the particular character of f with respect to R , and the first sign of summation extends to every form of the representative system) is identical with the series

$$\sum \left(\frac{P}{m} \right) \left(\frac{-Q}{n} \right) \frac{1}{(mn)^{1+\varepsilon}} \dots \dots \dots (B)$$

To verify this we observe (1) that, because $D \equiv 1$, mod 4, the numbers of sets of representations (art. 87) of N and $2N$ by forms of det. $-D$ are equal, N denoting any number whatever; (2) that, because D is not divisible by any square, the number of sets of representations of N by the forms of det. $-D$ is $\sum \left(\frac{-D}{d} \right)$, N denoting any uneven number, and d any divisor of N which is prime to D ; (3) that the generic character of a form f of det. $-D$ may be ascertained from any number whatever N which is represented by f ; in fact if p is a prime divisor of D , and if $N = N'p^{2\nu}$, N' being prime to p , we have $\left(\frac{f}{p} \right) = \left(\frac{N'}{p} \right)$; if $N = N'p^{2\nu+1}$, $D = D'p$, N' and D' being prime to p ,

$\left(\frac{f}{p}\right) = \left(\frac{N'}{p}\right) \left(\frac{-D'}{p}\right)$. From (1) and (3) we infer that the series (A) is equal to the series

$$\Sigma \left(\frac{f}{R}\right) \Sigma' \Sigma' \frac{1}{(ax^2 + 2bxy + cy^2)^{1+\rho}} \quad \dots \quad (C)$$

(in which the summations $\Sigma' \Sigma'$ extend only to those values of x and y for which f acquires uneven values); from (2) and (3), considering separately the two cases in which $R=P$, and $R=Q$, we infer that the coefficient of $\frac{1}{N^{1+\rho}}$ is the same in (B) and (C), N representing any uneven number; *i. e.*

that the two series (A) and (B) are identical.

Diminishing ρ without limit in the equation (A)=(B), and employing the equations (ii) and (iii), we find immediately

$$h(P).h(-Q).\log(T+U\sqrt{P}) = \frac{2}{3} \left[2 - \left(\frac{2}{R}\right) \right] \Sigma \left(\frac{f}{R}\right) \log \frac{a\sqrt{a}}{\theta'(0, \omega)\theta'(0, \omega')}, \quad (iv)$$

a remarkable equation which connects the least solution of the Pellian equation with the theory of the Theta functions.

If we suppose (as we may do) that the form (a, b, c) is reduced, so that $a < 2\sqrt{\frac{D}{3}}$, we may approximate to the values of $\theta'(0, \omega)$ and $\theta'(0, \omega')$ by omitting in their developments all terms after the first, and writing

$$\theta'(0, \omega) \times \theta'(0, \omega') = 4\pi^2 e^{-\frac{1}{2}\pi \frac{\sqrt{D}}{a}} + \dots$$

Substituting in (iv), we obtain the approximative equation

$$h(P).h(-Q).\log(T+U\sqrt{P}) = \left[2 - \left(\frac{2}{R}\right) \right] \Sigma \left(\frac{a}{R}\right) \left[\frac{\pi\sqrt{D}}{3a} + \log a \right]. \quad (v)$$

The following examples of this formula are given by M. Kronecker. If $Q=1$, the exponential $\frac{1}{8}e^{\frac{1}{2}\pi\sqrt{D}}$ is approximately equal to $2 + \sqrt{5}$, $18 + 5\sqrt{13}$, $882 + 145\sqrt{37}$ when we attribute to D the values 5, 13, 37; again, $\frac{2}{9}e^{\frac{5}{18}\pi\sqrt{17}} = 4 + \sqrt{17}$, $\frac{2}{49}e^{\frac{1}{2}\pi\sqrt{97}} = 5604 + 569\sqrt{97}$, if $D=17, 97$; lastly, if $D=85$, and we give to Q in succession the values 1, 5, 17, we find

$$\frac{1}{8}e^{\frac{3}{10}\pi\sqrt{85}} = 378 + 41\sqrt{85}, \quad \frac{1}{\sqrt{5}}e^{\frac{1}{10}\pi\sqrt{85}} = 4 + \sqrt{17}, \quad e^{\frac{1}{20}\pi\sqrt{85}} = 2 + \sqrt{5}.$$

These approximate representations of quadratic surds by exponentials are very remarkable; a similar observation had, however, already been made by M. Hermite*. If $D \equiv 3 \pmod{8}$, the equation of which the roots are the values of $\phi^8(\omega)$ corresponding to the improperly primitive classes of $\det. -D$, resolves itself into factors of the form $(x^2 - x + 1)^3 + \alpha(x^2 - x)^2 = 0$; and, in particular, if $\left(2, 1, \frac{D+1}{2}\right)$ is the only such class, α is an integral number. Attributing

to ω the value $\frac{-1 + i\sqrt{D}}{2}$, and substituting for x , or $\phi^8(\omega)$, its approximate value $x = 2^4(\epsilon^{i\pi\omega} - 8\epsilon^{2i\pi\omega} + 44\epsilon^{3i\pi\omega})$ (equation (14) or (26), art. 124), we find

$$\alpha = \frac{\epsilon^{\pi\sqrt{D}} - 744}{256}, \text{ nearly.}$$

Thus if $D=43$, M. Hermite has found that $\epsilon^{\pi\sqrt{43}} = 884736743.9997775\dots$; and that if $D=163$, the decimal part of $\epsilon^{\pi\sqrt{163}}$ commences with twelve nines.

* Théorie des Equations Modulaires, p. 48.

M. Kronecker states that the formula (iv) implies the resolubility of $\Psi_1(n, x)$ into its generic factors, and that conversely the resolution of that equation into its factors implies the possibility of expressing certain solutions (though not necessarily the least solution) of the Pellian equation by means of the modules which admit of complex multiplication. For the case when $D \equiv 5, \text{ mod } 8$, he has given the singularly elegant formula

$$\pi \frac{\sin \frac{a\pi}{D}}{\sin \frac{b\pi}{D}} = \pi \sqrt[3]{4\kappa^2\kappa'^2},$$

the first sign of multiplication extending to all numbers less than D and prime to it which satisfy the equations $\left(\frac{a}{D}\right)=1$, $\left(\frac{b}{D}\right)=-1$; the second to a certain sixth part of the modules which admit of complex multiplication with $\sqrt{-D}$. The formula may also be written in the form

$$[T-U\sqrt{D}]^{h(1)} = \pi \cdot 4\kappa^2\kappa'^2$$

(see Dirichlet, Crelle, vol. xxi. p. 151).

Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science. By a Committee, consisting of Lord WROTTESLEY, D.C.L., F.R.S., The Rt. Hon. C. B. ADDERLEY, M.P., Sir WILLIAM ARMSTRONG, C.B., F.R.S., THE ASTRONOMER ROYAL, F.R.S., SAMUEL BROWN, W. EWART, M.P., T. GRAHAM, F.R.S., Sir JOHN HAY, Bart., M.P., F.R.S., Prof. HENNESSY, F.R.S., JAMES HEYWOOD, M.A., F.R.S., Dr. LEE, F.R.S., Dr. LEONE LEVI, F.S.A., F.S.S., Prof. W. A. MILLER, F.R.S., Prof. RANKINE, F.R.S., Rev. Dr. ROBINSON, F.R.S., Colonel SYKES, M.P., F.R.S., W. TITE, M.P., F.R.S., Prof. A. W. WILLIAMSON, F.R.S., JAMES YATES, F.R.S., Sir ROBERT KANE, F.R.S., F. P. FELLOWS, C. W. SIEMENS, F.R.S., MATTHEW ARNOLD, M.A., Right Hon. Earl FORTESCUE, and FREDERICK PURDY, F.S.S.

At the Meeting of the British Association, held in Newcastle in 1863, a Committee was appointed to report on the best means of providing for a uniformity of weights and measures, with reference to the interests of science, and a report embodying certain recommendations was presented by the Committee to the British Association, at its last Meeting at Bath, which was received and adopted after considerable discussion in Section F, the Chemical and Mechanical Sections having also had the subject under consideration. The substance of these recommendations was the adoption of a decimal system of weights and measures, and the choice of the metric system on account of its scientific capabilities; the use of such metric system, as far possible, in statistical documents and scientific communications; the placing of metric standards in our public and frequented buildings; the teaching of the system in schools; and the use of it at the Custom House and Post Office. On the recommendation of the Section the Committee was then reappointed, and a grant was made to it of £20.

In furtherance of the object remitted to it, the Committee met and passed resolutions recommending the preparation of a small book for elementary instruction in the metric system, and the appointment of a Deputation to the President of the Board of Trade, for the purpose of representing to Her Majesty's Government the advantages of reducing the Tariff in the terms of the metric system, allowing importers of goods from countries using that system to pay duties calculated by the same; and also a Deputation to the President of the Committee of Council on Education, recommending the teaching of the metric system in schools supported by the State. It has been suggested, however, that the Committee had no power to do more than to report again on the subject to the Association, since the report of its Committee was only discussed and adopted in Section F, and not by the General Committee, and therefore it was deemed best to seek from the Association more definite power on the subject.

The Committee has pleasure in reporting that the necessity of introducing uniformity in weights and measures throughout the country is generally admitted, and that there is little or no difference of opinion as to the superior merits of the metric system, in the choice of which lies the only method for obtaining not only a thorough reform in our weights and measures, but also the great desideratum of international uniformity. By the Act of Parliament passed in 1864, the use of the metric system in this country was legalized, and thenceforth a contract has become equally enforceable whether in the terms of the metric system or in the terms of the imperial standards. Since, however, the use of the same is at present optional only, and not compulsory, much remains to be done, not only in recommending the practical use of the metric system in the different branches of business and industry, but also in disseminating the necessary teaching of the same, especially in schools and colleges, with a view to its more general adoption.

The Committee has learnt that the metric system is already in use in many great establishments. Those especially which supply machinery to the Continent of Europe are under the necessity of using the metric measurement in fulfilling their orders, and it does not appear that the workmen in such establishments have any difficulty in understanding the system, and in using it with as much readiness as the imperial scale. Since the last Meeting of the British Association, the Institution of Mechanical Engineers, at their meeting in Birmingham, had a favourable opportunity for discussing the question, a paper having been prepared for them by Mr. John Fernie, a member, on the relative advantages of the inch and the metre as the unit of a decimal line or measure. On that occasion, Sir William Armstrong, Mr. C. W. Siemens, F.R.S., and Mr. Robinson of the Atlas Works, all practically acquainted with both systems, recorded their opinion decidedly in favour to the metre; and though in accordance with the rules of that Institution no resolution was passed, there is reason to believe that a large number of members were of opinion that the metric system was in every way preferable. Another important testimony in favour of that system was also given by a Committee of the Liverpool Chamber of Commerce, especially appointed on the decimalization of coins, weights, and measures. That Chamber, in common with many other Chambers of Commerce, petitioned Parliament in favour of the Bill since passed into law; and now, after mature inquiry, we find a Committee of that Chamber recommending the ultimate adoption, *and at no distant period*, of the metric system of weights and measures *as the sole legal system in this country*. The teachers are also moving. At a meeting of Professors, Teachers, and others interested in education held in Birmingham, on Wed-

nesday, the 15th of March, 1865, Rev. Charles Evans, M.A., Head Master of King Edward's Grammar School, in the chair, it was unanimously decided, "That, having regard to the merits of the metric system of measures and weights now legalized in this country by Act of Parliament, to the facility with which it may be learnt and afterwards retained in the memory, to the great saving of time which would thereby be gained in education, to the convenience it offers for the largest as well as the most minute calculation, and to the decided advantages of the decimal method in any arithmetical system, this meeting is of opinion that the metric system of measures and weights should be introduced as a branch of instruction in the schools of the United Kingdom." At a meeting of British teachers connected with the British and Foreign School Society in the Borough Road, London, the same question was discussed, and there is no doubt that the teachers see the importance of giving instruction in a system which will speedily replace the present uncouth practice. What is now wanted for the purpose of education is a book sufficiently elementary yet complete in itself, likely to be used as a text book in all schools and colleges. Several books on arithmetic already give considerable prominence to the decimal and metric system. More especially we may mention the treatises on Arithmetic by the Rev. Barnard Smith, Mr. Dowling's Comparative Tables, and also the useful Ready Reckoner published in this town by Mr. Rickard, the able teacher in King Edward's School. In Continental schools M. Carpentier's "*Nécessaire Métrique*," which is a small cabinet containing samples of all the smaller weights and measures, the cubes, &c., is largely used, and there is no doubt that the children on the Continent obtain much more early in life an accurate knowledge of numbers, their properties, and their combinations, with the metric system than the English boys do with the imperial scale.

Nowhere could we see more clearly the need of altering the present practice than in the practical routine work in railway management. With the enormous traffic of our railway companies, the inconvenience of the present subdivision of weights produces a decided appreciable loss to the income of the shareholders. For example, the London and North-Western Railway Company, whose annual income equals the entire revenue of the majority of European states, carries to every station in the Empire some thousands of packages of all sizes, many exceedingly small, and nearly all having fractions of weights. At the head station in Camden Town nearly 1200 entries are made of such packages every day, which are sent to the station in the course of the day, and despatched on the same evening. Before they are sent, however, such packages must nearly all be weighed or measured, and taxed at a great variety of rates. But great is the liability to error arising from our cumbrous system, when the calculations are to be performed in a hurried manner. It is in fact calculated that, on an average, the clerks commit one error in every 500 items; and the consequence is that the London and North-Western Company are under the necessity of nearly doubling the number of clerks. For every 100 clerks employed in weighing, or measuring and taxing packages, nearly another 100 are wanted to correct the errors committed. But with a decimal and metric system this liability to error is immensely reduced, and therefore a practical economic benefit would certainly arise from the adoption of that system in railway traffic. A Royal Commission has been recently appointed on railway management, and they are to inquire into the more economic arrangements for the working of railways, so as to make a considerable reduction in the cost of conveyance. This is a favourable opportunity for calling attention to the question, and the Committee is pleased to find that the Council of the Inter-

national Decimal Association has offered to give evidence before the Commission on the subject.

As a practical mode for diffusing information on the metric system, it has been suggested to fix the metric standards in one or more frequented places in the leading commercial cities of the empire. The Act for rendering permissive the use of the metric system did not provide for the introduction of standards, but only furnished a table of equivalents of the metric and imperial systems. It would, however, be highly desirable to furnish the people with the means of ascertaining the accuracy of the metric weights and measures used by comparison with certain authorized standards. The great want seems to be a Weights and Measures Department connected with Government, as was recommended by the Committee of the House of Commons, whose duty it should be to procure such standards, and to superintend the necessary arrangements for the security of trade and the diffusion of sound information on the subject. Till recently the control of the imperial standards was in the hands of the Comptroller of the Exchequer, but since that office has been abolished and incorporated with the Audit Office, it has become almost imperative to establish such a department. It would be desirable that such a department should supervise the examination and comparison of the weights and measures in use throughout the country, superintend the Inspectors now appointed by the municipal councils of each town, and more especially issue such tables, books, and specimens of the metric system as will diffuse information of the same throughout the country. This is the plan which has been adopted with great success wherever the metric system has been established. And we are glad to find that the Committee of the Liverpool Chamber of Commerce has recommended the same course in the following resolution:—"That a Department of Government of weights and measures should be established, subordinate to the Government and responsible to Parliament, to whom should be entrusted the conservation and verification of the standards, the superintendence of inspectors, and the general duties incidental to such department. That these duties should especially include the use of all means for promoting the use and extending the knowledge of the metric system among the people."

The Committee has observed with much pleasure, that in several scientific communications in the Transactions of the Royal Society, and some official documents issued by the Government, metric weights and measures are given side by side with the imperial. In many cases, indeed, a decided preference seems to be given to the former, especially in papers on chemical science. It is greatly to be lamented that the Pharmaceutical Society did not adopt the metric system, the same not being then legal, when settling a new Pharmacopœia; the mixed system they have adopted was far from meeting general approbation, and they will be under the necessity of making a new change.

In foreign countries the principal movement in favour of the metric system is in Germany. For some time past the different German States have been labouring towards the attainment of greater national unity; and, after having come to an agreement about the coinage, they have given their attention to the state of weights and measures in use in the different States. In 1862 a conference was held at Frankfort for the purpose of concerting as to the choice of one common system, when official delegates were present from nearly all the principal states except Prussia, and after much discussion they recommended the adoption of the metric system.

Since then the International Statistical Congress having been held at Berlin, their proceedings regarding international units, had due influence on the Prussian Government, and it is expected that the opposition of that Government may have thereby been overcome. Another meeting of the same Congress of delegates from German States has just been held at Frankfort, with the presence of Prussian delegates, and we trust to hear speedily of the unanimous resolution in favour of the adoption of the metric system.

Though the instructions of this Committee are confined to weights and measures, and do not include coins, the Committee are convinced that the advantage of the metric and decimal system will not be fully realized until the coins also and mode of accountancy are decimalized.

In conclusion, the Committee would recommend the reappointment of this Committee with power to use such measures as it may deem expedient for promoting the extensive use of the metric system in scientific and official documents, in the Custom House and Post Office, as well as the teaching of the system in schools and colleges; with instructions also, as regards the coinage, to represent to Her Majesty's Government the expediency of the early adoption of such a system of decimalization as will the more effectively facilitate the social and commercial transactions of the country, and at the same time advance the great purpose of international exchanges, and especially to urge upon Her Majesty's Government the great benefit that would arise from the early assembling of an international monetary convention, as recommended at the last meeting of the International Statistical Congress, held at Berlin.

On the Bed of the Ocean. By A. G. FINDLAY, F.R.G.S.

THE progress which has been made of late years in deep-sea sounding, chiefly in connexion with the selection of a route for the Atlantic Telegraph Cable, and the curious results it has developed, led to the desire, at the Bath Meeting, that a wider and more systematic survey of the ocean bed should be carried on, and for this purpose the General Committee appointed Sir R. Murchison, Rear-Admiral Collinson, and Mr. A. G. Findlay, to endeavour to promote this object.

Up to the present time we know less of ocean physics than of almost any branch of science. The volume, depth, circulation, temperature, &c. of the waters of our globe are only vaguely to be surmised from isolated and imperfect experiments; yet it has an influence on physical geography second only to that of the atmosphere.

The fact of animal life existing at the greatest depths, and of exactly the same nature, under every variety of surface climate, has only lately been satisfactorily determined.

The wide range of speculation which the late accessions to our knowledge as to the perpetual interchange and circulation of the whole of the ocean water, from the surface to the bed, from the equator to the poles, by which it would seem that the universal identity of its nature and composition could be maintained, the wide area over which species of animal life are found, the formation and composition of the sedimentary and oolitic rocks now in progress, are of apparently the same character as our older geologic strata.

The state of our knowledge of the whole is detailed by Dr. Wallich

in his work on the Atlantic sea-bed, and he will lay before this Meeting a description of the mode of sounding.

From the nature of the work to be done, it is manifest that individual efforts cannot be made available. The apparatus is both cumbersome and costly, and it requires a small steam-engine to use it. It must therefore be left to Government.

Perhaps the best form of apparatus, and the relation of the sounding lines to it, have not yet been determined; but it is believed that, when these preliminary matters are fully adjusted, the work could be carried out with celerity and certainty; and if the services of some of the vessels of Her Majesty's Navy could be impressed, we should soon have an accumulation of data whereon a satisfactory system of ocean physics might be raised.

For the direct benefit of seamen also, we should have the means of proving, or, what is better, of disproving the existence of the great number of reported shoals and dangers which embarrass navigation.

In furtherance of the views of the Committee of Recommendation, Admiral Collinson has conferred with several officers since the last Meeting.

There may be some difficulties as to the mode of carrying out the plan desired by the Committee in its full extent; but the recent adoption of steam launches in the navy might give the necessary steam power, and some form of apparatus will have to be adapted to the special cases of those vessels not otherwise properly fitted. But the subject has made some progress. Commander C. Bullock, R.N., the Oriental Surveyor, son of Rear-Admiral Bullock, has been supplied with apparatus for H.M.S. 'Sphinx,' under his command, and he will doubtless send home good accounts of it in his progress toward the Indian Archipelago, and in the seas north of Australia, to which his expedition is bound.

The first instalment of the observations has not yet arrived, but is expected shortly. We therefore hope that by the next Meeting some considerable advances will have been made in this interesting subject, and which, as far as possible, will be laid before the Meeting.

On the Composition of the Gases evolved by the Bath spring called King's Bath. By Prof. A. W. WILLIAMSON, University College, London.

It was at the suggestion of Dr. Daubeny, who examined the gases from the Bath water in 1832, and measured the quantity evolved per hour, that the Association did me the honour to request me to undertake an analysis of the gas, and to make arrangements for its careful collection. I understood that one reason for desiring these experiments to be made, was the possibility that variations might have occurred in the rate of their evolution since the time of Dr. Daubeny's analysis.

On inquiring of the authorities in Bath, I learned that there are in that city no less than four hot springs, each of which continually evolves gas simultaneously with hot water. These springs supply respectively the King's Bath, the royal private bath in Hot Bath-street, the Cross Baths, and the Kingston Baths.

2.

| | | |
|---|---------|---|
| Gas taken | 245·692 | } Diff. 8·636 = 3·511 per cent. of carbonic acid. |
| After 15 minutes' contact with potash.. | 237·056 | |
| After 15 minutes' more contact | 237·056 | |
| After explosion with oxyhydrogen gas.. | 240·917 | } An increase of 1·63 per cent. Showing ·1 per cent. of oxygen. |
| After addition of hydrogen | 279·524 | |
| After explosion with oxyhydrogen gas.. | 278·807 | |

3.

| | | |
|---|---------|--|
| Portion of gas free from carbonic acid taken | 268·282 | } Being an increase of ·83 per cent. |
| After explosion with oxyhydrogen gas.. | 270·509 | |
| Same gas, after exploding again with oxyhydrogen gas..... | 274·608 | } Being a still further increase of 1·52 per cent. |
| | | |

Bottle No. 4.

Fixed at 2 P.M.

Marked at 5.45 P.M.; Therm. 65°·8 F.; Barom. 30·05 inches. Contents to marks 1870 cub. centims.

= 1760 cub. centims. at 0° Cent. and 760 millims. in 40 seconds.

880

= 2640 cub. centims. per minute.

1.

| | | |
|--|---------|---|
| Gas taken | 242·999 | } Diff. 7·162 = 2·948 per cent. of carbonic acid. |
| After 10 minutes' contact with potash.. | 235·837 | |
| After 10 minutes' more contact | 235·837 | |
| Measured next morning | 236·04 | } Difference or absorption 1·016, or ·42 per cent. of oxygen. |
| After 1 hour's contact with potassic pyrogallate | 235·024 | |
| After another hour's contact..... | 235·024 | |
| After addition of air..... | 295·055 | } Being a contraction of 1·164 on the gas taken, or of ·48 per cent. |
| After explosion with oxyhydrogen gas.. | 293·891 | |
| After ten minutes' contact with potash.. | 292·879 | } Showing the formation of ·42 per cent. of carbonic acid, calculated on the gas taken. |
| No alteration on longer contact. | | |

2.

| | | |
|---|---------|--|
| Gas taken | 175·9 | } Difference 5·376 = 3·056 per cent. of carbonic acid. |
| After contact with potash..... | 170·524 | |
| After longer contact | 170·524 | |
| After contact with potassic pyrogallate | 169·6 | } Absorption ·924 = ·525 per cent. of oxygen. |
| After longer contact | 169·6 | |
| After addition of air..... | 245·082 | } Contraction ·914, or ·52 per cent. on the gas used. |
| After explosion with oxyhydrogen gas.. | 244·168 | |
| After absorption of carbonic acid..... | 243·457 | } Showing the formation of ·4 per cent. of carbonic acid, calculated on the gas taken. |
| After longer contact with potash | 243·457 | |

Bottle No. 5.

Fixed at 9.15 A.M.

Marked at 11.30 A.M.; Therm. $64^{\circ}4$ F.; Barom. 30.15 inches. Contents to marks 1975 cub. centims.= 1867.5 cub. centims. at 0° Cent. and 760 millims. in 45 seconds.
622.5

= 2490.0 cub. centims. per minute.

| | | |
|--|---------|--|
| Gas taken | 219.498 | } Absorption 5.982 = 2.721
per cent. of carbonic acid. |
| After 10 minutes' contact with potash.. | 213.516 | |
| After 10 minutes' longer contact | 213.516 | |
| After half-hour's contact with potassic
pyrogallate | 212.69 | } Absorption .826 = .376
per cent. of oxygen. |
| After another half-hour | 212.69 | |
| After addition of air | 282.354 | } Contraction 2.42 = 1.1
per cent. on the gas used. |
| After explosion with oxyhydrogen gas.. | 279.934 | |
| After contact with potash | 279.022 | } Absorption .912, showing
the formation of .416
per cent. of carbonic acid. |
| After longer contact | 279.022 | |

Bottle No. 3.

Fixed at 1.10 P.M.

Marked at 4 P.M.; Therm. $65^{\circ}3$ F.; Barom. 30.04 inches. Contents to marks 2000 cub. centims.= 1880 cub. centims. at 0° Cent. and 760 millims. in 50 seconds.
376

= 2256 cub. centims. per minute.

Bottle No. 6.

Fixed at 10.15 A.M.

Marked at 1 P.M.; Therm. $64^{\circ}1$ F.; Barom. 30.15 inches. Contents to marks 2325 cub. centims.= 2200 cub. centims. at 0° Cent. and 760 millims. in 70 seconds.
314

= 1886 cub. centims. per minute.

Two or three small bubbles of air entered this bottle on opening.

Bottle No. 7.

Fixed at 2.15 P.M.

Marked at 4.45 P.M.; Therm. $64^{\circ}3$ F.; Barom. 30.15 inches. Contents to marks 2150 cub. centims.= 2016 cub. centims. at 0° Cent. and 760 millims. in 55 seconds.
183

= 2199 cub. centims. per minute.

A few bubbles of air entered on opening.

Bottle No. 8.

Fixed at 5 P.M.

Marked at 10 o'clock next morning; Therm. 66° F.; Barom. 30.125 inches. Contents to marks 1895 cub. centims. = 1784 at 0° Cent. and 760 millims. in 60 seconds.

Composition of Gases in 100 volumes.

| | | Carbonic acid. | Oxygen. | Marsh-gas. | Carbonic oxide. | Nitrogen. |
|----|-----|----------------|---------|------------|-----------------|-----------|
| 2. | I. | 3.454 | .19 | | | |
| | II. | 3.511 | | | | |
| 4. | I. | 2.948 | .42 | .18 | .24 | 96.212 |
| | II. | 3.056 | .525 | .216 | .186 | 96.019 |
| 5. | | 2.721 | .376 | | | |

The carbonic oxide was no doubt produced by the potassic pyrogallate; allowing for this, the composition of the gases will be

| | | Carbonic acid. | Oxygen. | Marsh-gas. | Nitrogen. |
|----|-----|----------------|---------|------------|-----------|
| 2. | I. | 3.454 | .19 | | |
| | II. | 3.511 | | | |
| 4. | I. | 2.948 | .54 | .18 | 96.332 |
| | II. | 3.056 | .617 | .216 | 96.111 |
| 5. | | 2.721 | .376 | | |

No. 2 gave 2311 cubic centimetres per minute.

| | | | | |
|----|-------|---|---|---|
| 4 | 2640 | „ | „ | „ |
| 3 | 2256 | „ | „ | „ |
| 5 | 2490 | „ | „ | „ |
| 6 | 1886 | „ | „ | „ |
| 7 | 2199 | „ | „ | „ |
| 8 | 1784 | „ | „ | „ |
| 7) | 15566 | | | |

Mean 2223.7 cubic centimetres of gas at 0° Cent. and 760 millimetres mercurial pressure per minute.

Method of collecting Gases from the King's Bath at Bath.

The bottle marked 1 to be taken from box at a time when there is a depth of eighteen inches of water in the bath.

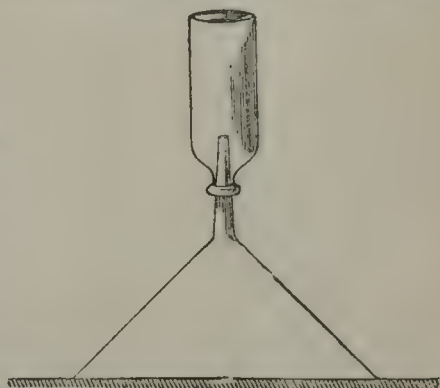
The string by which its stopper is attached to be cut, and the stopper (enveloped in paper) to be put in waistcoat pocket of operator. The bottle to be filled with water by immersing it in bath mouth upwards, until all the air has escaped from it.

Tin funnel to be placed over the opening through which water flows into the bath, in such a position that all the gas which bubbles up from the spring will rise into the funnel.

Bottle full of bath water to be inverted over funnel and left there until quite full of the gas. The bottle is then to be carefully lifted off the funnel, its mouth being constantly kept under water, and again filled with water in the same manner as before, viz. by immersing it in the bath until all the gas has bubbled out of it.

When thus filled with water a second time, the bottle is to be slipped over the mouth of the funnel at the moment that an assistant, holding a watch marking seconds in his hand, calls out that the seconds' hand is at the point marked o on the scale.

1865.



The bottle is to be left over the funnel until $\frac{3}{4}$ or $\frac{2}{3}$ of the water is driven out of it by the gas, and the assistant being warned that the time for stopping the collection is approaching, the bottle is to be lifted off the funnel at the instant that the assistant calls out that the seconds' hand of the watch has arrived at the point marked *o* on the circle, so that it has completed an entire number of revolutions since the collection of gas commenced.

The exact time at which the collection began is to be written down by the assistant while the operator is collecting, and in the line marked with the number of the bottle, and the time at which the collection ceases to be written down by the assistant in the same table when the operation of collecting is complete.

The stopper is to be immersed, held by its handle, in the water of the bath for some minutes before the collection is complete, and pressed firmly into the mouth of the bottle while that mouth is under water and held downwards.

The stopper is then to be firmly tied down into the neck of the bottle, the bottle returned to its place in the box, and the box locked up again till next period of collecting.



NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

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MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Address of W. SPOTTISWOODE, F.R.S., President of the Section.

THE great range of subjects comprised in this section, and the multiplicity of papers submitted to it, have doubtless contributed to deter my predecessors in this chair from preparing addresses so elaborate and comprehensive as those delivered to other sections. The custom, however, of prefacing the business proper by a short summary of subjects which have engaged the attention of philosophers during the past year, and which may therefore be expected to come before us during our present sittings, appears to be sanctioned by the wishes of our members, and may perhaps be followed without materially departing from that brevity which is here both customary and desirable. Foremost among the astronomical subjects in which we may hope to receive communications are the researches of Messrs. De la Rue, Stewart, and Loewy, in solar physics. Without attempting to anticipate what they may have to state, it may be as well to remind the section that it seems now to be established that solar spots are at a lower level than the penumbrae, the faculae at a higher; that the photosphere is gaseous; and that the behaviour of the spots, as to appearance and disappearance, is connected with the position of the planets, and principally with that of Venus. The objection to this view of the nature of sun-spots which has been raised on the ground of the unbroken curvature of the sun's limb, notwithstanding the elevation of the faculae and depression of the spots, has been answered by Professor Phillips in a paper read before the Royal Society. That the central mass is of less brilliancy than the photosphere is also ascertained; but whether this arises from solid matter at a lower temperature, or otherwise, is still a question. M. Faye, in an elaborate memoir presented to the French Academy, suggests that it may consist of transparent gas.

The moon continues to be the subject of careful investigation, both theoretical and observational. M. Delaunay explains that the delay in completing the second part of his lunar theory arises from his having to carry his developments beyond the order originally contemplated, viz. the seventh—in some cases as far as the ninth. M. Allégret states that the terms involving the cube of the time became important when determining the secular variations. Under this head mention must not be omitted of Professor Cayley's valuable contributions to the lunar theory.

The Lunar Committee of this Association have been most actively engaged during the past year, and will state the results of their labours in their report.

The planet Mars has been the object of much telescopic research on the part of our President, Messrs. Dawes, Lockyer, and others. The supposition that the

redder parts of its disk are land, and the greyer parts sea, appears to be verified; recent observations also confirm the view that snow is visible in its polar regions. Comparing the latitudes of arctic climates on Mars with those on the earth, it has been concluded that the temperature on the two planets is not very different. The solar radiation in the two cases is, of course, very disproportionate; but the explanation of the result is to be sought in the action of a dense atmosphere, which, as Professor Tyndall has shown, serves to retain large quantities of heat which would otherwise radiate into space.

Mr. Lassell has communicated to the Royal Astronomical Society an ephemeris of the satellites of Saturn, now finally reduced to four.

The number of the minor planets continues to increase. M. Serret has presented to the Academy of Paris a theory of the movement of Pallas, complete as regards the perturbations of the principal planets. He promises a second part, discussing the influence of the minor planets, in which he states that he has arrived at some curious and unexpected results.

Although the subject of auroras more properly belongs to that of terrestrial magnetism, it may here be mentioned that the height of these phenomena has been determined to be from 35 to 290 miles. Meteors and falling stars, whose periodic visits in August and November are well known, have both, by the labours of Alex. Herschel, Quetelet, and Secchi, been shown to be minute planetary bodies, differing only in size. When visible, they pass at a height of from fifty-two to seventy-three miles above the surface of the earth. M. Deville has even attempted to account for the known depression of temperature in February and May, and the elevation in August and November, by their position intercepting the heat of the sun during the former periods, and preventing the heat from the earth radiating into space during the latter.

Before leaving our solar system, we must notice the discussion which has arisen respecting an expedition to the Antarctic regions to reconnoitre for practicable stations for the observation of the transit of Venus in 1882. It is unnecessary to remind this section that upon accurate observations of this phenomenon, at proper points upon the earth's surface, will depend a verification or otherwise of M. Foucault's correction of the sun's distance, due to his new measurements of the velocity of light. The question of the expedition, however, will doubtless be fully discussed in the geographical section.

A celestial atlas, just published by M. Dien, promises to surpass all its predecessors in accuracy of detail. The difference of longitude between points on the great arc of parallel—Bonn, Nieuport, and Haverfordwest—has been carefully observed; so has the longitude of the observatory at Glasgow.

The usual amount of attention has been paid by observers and calculators to the subject of comets and their orbits. But, besides this, M. Hock, in a paper presented to the Royal Astronomical Society, has argued in considerable detail in favour of his view that comets move in parabolic and hyperbolic orbits, not in ellipses—that they are not isolated bodies, but consist of groups of fragments of bodies broken up by the sun or planets.

Passing to the more remote celestial objects, Mr. Huggins has been continuing his observations on, and has determined, the spectra of the fixed stars and nebulae, of which we may hope to hear some further particulars. In the meantime, I will notice only one point, but that a very curious one. Lord Rosse and Professor Bond find, by telescopic observations, that the brighter portions of the great nebula in Orion are apparently resolvable into stars. Mr. Huggins's analysis, on the other hand, gives a spectrum consisting of three bright lines only, indicating a gaseous condition. An explanation of this apparent contradiction is perhaps to be found in the suggestion that the bright points shown by the telescope are not stars in the ordinary sense of the term, but condensed parts of the nebulous fluid. Imagination would lead us to suppose that we have here before us a stage of cosmical process intermediate between nebula and stars—the formation of a sun; but strict science forbids us as yet to adopt this as an ascertained conclusion.

Spectrum analysis continues to receive further additions at the hands of the chairman of our Kew Committee, Mr. Cassiot, who has carried the question so far as to construct an apparatus for determining whether the so-called fixed lines of the

solar spectrum undergo any displacement through the variation of gravity, in passing from one latitude to another on the earth's surface.

The operations at the Kew Observatory in terrestrial magnetism, and with the pendulum apparatus recently erected there, will form the subject of a separate report. In the former department the observations at Stonyhurst give, as the annual secular decrease of dip for the mean epoch of 1861-69, $2'614$ —a result not very different from that determined by General Sabine for London, viz. $2'69$. From the same quarter we are informed that the annual increase of total force is 0.0030 British unit. Although this requires observations continued over a longer period, it may still be regarded as confirmatory of the fact that the total force is increasing.

To Professor Tyndall's researches in radiant heat allusion has been already made. From himself, however, we hope to receive a communication on his more recent experiments, whereby he has been enabled entirely to cut off the luminous from the calorific rays, and to produce not only combustion in an absolutely dark focus, but also the incandescence of platinum by non-luminous rays.

Among the experimental improvements in subjects kindred to this may be mentioned M. Marcus's new thermo-electric battery, an invention likely to render this kind of battery far more generally serviceable than has hitherto been practicable. Like many other inventions, this has not been without some kind of anticipation, in a suggestion by Mr. Wheatstone in 'The Philosophical Magazine' as long ago as 1837.

We should also notice a suggestion by M. Carlier, for dispensing with the covering of the wire in electric coils. It is said that this has been carried out with such success as to produce an increase rather than diminution of power. M. Richer also suggests the use of sulphur plates instead of glass in electrical machines. Mr. Beale has succeeded in using object-glasses for the microscope of much higher power ($\frac{1}{5}$ in.) than heretofore; and I must not omit to mention that an essential part of the apparatus consists of a cap of the thinnest possible glass, manufactured only by Mr. Chance of this city.

From the Committee on Electrical Resistance we shall doubtless receive a further report. But the gigantic experiment to which the whole subject has recently been subjected—an experiment which, notwithstanding its present interruption, we may still call a great scientific success—will doubtless give an additional interest to anything that the members of the committee who accompanied the Atlantic expedition may have to communicate.

Side by side with these experimental researches, the mathematical theories of molecular physics have been advanced in several directions. Professor Maxwell, in this country, and M. Renard in France, have each contributed a memoir on electro-dynamics; and the latter has deduced his fundamental formulæ from the hypothesis of a single fluid. M. Cornu, by a happy application of M. Chasles's principle of homographic planes, has deduced from MacCullagh's theory some propositions relating to crystalline reflexion and refraction. These have the remarkable property of being independent of the wave-surface, and therefore may be said to rest upon a simpler frame of hypothesis. M. Cornu is preparing some apparatus for the experimental verification of his method. M. Boussineq also has presented to the Academy of Sciences a memoir on the theory of light, in which he has taken into account terms of the second degree in the displacements. It would seem that the paper contains generalizations comprising the theories of Fresnel, MacCullagh, and Neumann. Lastly in this connexion may be mentioned the writings of M. Saint Venant on the *vis viva* of elastic systems, and his extension of the investigations of Navier and Poncelet on the resistance of elastic bars, rods, &c.

In each of the main branches of pure mathematics, geometry and analysis, a modern school has arisen. The former, originating with Carnot, Dupin, Poncelet, and others, dates from the early part of the present century; the latter, due in the first instance to Cayley, Boole, and Sylvester, belongs wholly to the present generation. Both schools have this in common, that figures in the one case, and forms in the other, are considered not merely as isolated individuals, but as associated with other concomitant forms which characterize their various properties.

In pure geometry we have the principle of projection, whereby any plane figure is considered in connexion with all or any other plane figure lying on the same

cone, in such a way that a theorem relating to one figure frequently establishes a corresponding theorem relating to the other. Thus many properties of conics in general are at once suggested and proved by reference to the circle.

Again, the theory of reciprocal polars, or rather the principle of duality, which enables us to see points and straight lines in a condition of interdependence such that theorems relating to points (*e.g.* positions or curves, intersections of lines, &c.) at once give rise to corresponding theorems relating to straight lines (tangents, rectilinear loci, &c.). Under the head of modern geometrical methods falls also the theory of pencils of rays and transversals; straight lines radiating from a point and cutting another line, straight or curved. This again suggests the idea of relations between the segments of the transversal (when straight) or between the angles made *inter se* by the radiating lines. The most fruitful conception of this kind has been that of the anharmonic ratio of four points or rays. This peculiar ratio remains unchanged under such a variety of circumstances, that it has arisen to an almost independent principle in geometry; and upon it M. Chasles may be said to have founded, to a very great extent, his '*Geométrie Supérieure*' and his new work on conic sections, the first volume of which has recently appeared. Before quitting this part of the subject, it should not be omitted that a great part of these theories have their application to figures in space as well as to those *in plano*.

The second volume of M. Chasles's work will contain a full exposition of his recent most important contribution to the theory of conics. He has found that the properties of a system of conics satisfying any four conditions whatever may be most naturally expressed in terms of two elements or *characteristics*—namely, the number of such conics which pass through any point, and the number which touch any line. Starting from this fruitful notion, he has, in a process which may be termed *geometrical substitution*, been able to express, in a single symmetrical formula, the number of conics which satisfy any five conditions whatever. We may almost say that he has condensed into this formula the whole theory of conics.

Again, connected with this is the principle of deformation—another method of considering one figure in relation to another, the points of the one being connected by a definite construction with those of the other. By this, and in particular by a most happy extension of it by Professor Hirst, theorems and properties of curves of higher degrees are demonstrated through those of lower, *e.g.* curves of the fourth and fifth degrees by conics.

Passing to analysis, we have in the first place the analogues of the geometrical theories above mentioned. To the method of projection corresponds (in one of its interpretations at least) the method of linear transformation; to that of deformation, non-linear transformations. The method of transversals as well as those of anharmonic ratio and geometrical involution admit of a concise analytical statement; but they cannot be called methods even in analytical geometry, still less in analysis proper. The principle of duality, however, as treated by Plücker, may claim an analytical with as good a right as a geometrical basis.

Before quitting this part of the subject, mention should be made of two important and original contributions to analytical geometry in space. One, by Professor Cayley, is directed to the representation of curves in space (by means of cones having variable vertices), a method free from the extraneous branches sometimes introduced by the ordinary conception of the complete intersection of two surfaces; of the other, by Professor Plücker, we have at present only the abstract in the proceedings of the Royal Society; it promises, however, to abound in processes of great power and originality.

But the greatest acquisition to modern analysis is what is now generally termed the new algebra. This calculus, which originated in this country, and from the first received wide developments at the hand of its founders, Boole, Cayley, and Sylvester, has, during the last few years, found numerous cultivators both amongst ourselves and on the Continent. The main problem proposed for solution is the investigation of the properties of rational homogeneous algebraical functions of any number of variables, the forms to which they are capable of being reduced, the subsidiary expressions to which they give rise or with which they may be associated, and the bearing of the latter upon the former. Investigations so general, so abstract, and so apparently removed from any practical application could not

fail to be regarded coldly by many whose attention had been principally directed to special problems in physics. And one at least of my hearers will doubtless, with myself, recollect the unrestrained censure which, in the midst of a most hearty greeting, the late astronomer of Turin would pour upon the labours of any disciple of the modern school who chanced to visit him. The promoters, however, of this science, sure of their footing, and confident that nothing which could lead to results of such a remarkable character or of such great generality, that nothing which could unite, correlate, and simplify the apprehension of such numberless *disjecta membra* of analysis—confident that no such method would in the end prove useless or unmeaning in the interpretation of nature—pursued their investigations; and a very short time has justified their firmness, by witnessing the new algebra reaching out and indissolubly connecting itself each year with fresh branches of mathematics. The theory of equations has almost become new through it; algebraic geometry has been transfigured in its light; the calculus of variations, molecular physics, and mechanics have all felt its influence.

The memoirs of Cayley on quantics, those of Sylvester on the calculus of forms, have become classical. Intimately connected with this subject is the theory of numbers, which, at the hands of some leading analysts, principally German and French, has recently received such large extension. One peculiarity, but that of a very general character, which distinguishes some of the modern from the older methods, consists in the introduction of variable quantities into the expressions—in other words, in bringing the processes of continuous to bear upon the properties of discrete quantity. But into this it is unnecessary to enter in any detail, as we have already in our volumes the very able and comprehensive reports by Professor Smith, of Oxford. We are now anxiously expecting his final communication, not only because we shall then have before us a survey of the whole subject brought down to the present time, but still more because we trust that the author may then find leisure to complete the original work upon the theory of numbers upon which it is understood that he has been engaged for many years, and to which the reports in question form only a prelude.

The tendency which is here exhibited of some common principle running through various subjects, and bringing them into connexion, reappears in the differential resolvents of Cockle, Harley, and others, and in the transcendental solution of equations which has been effected on the Continent. In both cases a relation is established between ordinary algebraic equations and the differential calculus—in the one with linear differential equations, in the other with a simple integration. Some future developments will, perhaps, throw further light upon the ultimate issue of these processes.

The calculus of operations, or of symbols, as it has been also called, whereby the symbols of operation are separated from those of quantity, has for some years been in use among analysts in this country. And although no very remarkable step has recently been made, or is perhaps to be expected, in this field, still some considerable progress has been effected towards completing the algebra, or laws of combination, of these non-commutative symbols.

It would occupy too much time to touch upon the many more subjects which suggest themselves, but it would be impossible to pass over without mention the important contributions to the theory of differential equations, and in particular of those which occur in mechanics, by the late Professors Jacobi and Boole (in whose deaths mathematical science has sustained so great losses), and, secondly, the extension which the theories of elliptic and Abelian functions have received at the hands of Riemann, Hermite, Weierstrasse, Clebsch, and others. The last-mentioned mathematician has brought the subject of Abelian functions to bear in a most remarkable and unexpected manner upon algebraic geometry.

I will allude to only one more instance of modern generalizations—namely, the conception of imaginary quantities introduced alike into geometry and algebra, one of the most fertile sources of new and important theorems. The funeral on this very day of one of our most profound mathematicians—Sir W. R. Hamilton—the inventor of quaternions, invests the subject with a somewhat mournful aspect on the present occasion. And here I must bring this brief and imperfect sketch of recent progress in our subjects to a close. It would have been more

interesting to myself, and more justice would have been done to the writers whose names have been little more than mentioned, if I could have completed the outline, or, better still, have filled in the details. As it is, some apology is due for having so long detained you upon mathematics; but, as a science whose rules all others must obey, it has large claims upon our attention; and if a personal motive must also be confessed, one's mind lingers upon a favourite subject.

MATHEMATICS.

On Dual Arithmetic. By O. BYRNE.

The author explained his method of dual arithmetic, which he has applied, in connexion with the calculus of form, to investigate the relations and properties of angular magnitudes and functions, plane and spherical trigonometry, &c.

On certain Theorems in Laplace's Discussion of the Figure of the Earth and Precession and Nutation. By Prof. A. H. CURTIS.

On the Theory of Differential Resolvents. By the Rev. R. HARLEY, F.R.S.

The theory of differential resolvents owes its origin to the discovery that, from any algebraic equation of the degree n , whereof the coefficients are functions of a variable, there may be derived a linear differential equation of the order $n-1$, which will be satisfied by any one of the roots of the given algebraic equation. These differential equations are now known by the name "differential resolvents." The author explained how they are formed, and pointed out their connexion with the theory of algebraic equations.

One of the most important of his recent results is the following:—

If u represent the m th power of any root of the algebraic equation

$$y^n - ny^{n-r} + (n-1)x = 0,$$

then u , considered as a function of x , satisfies the linear differential equation

$$n^n \left[\frac{n-r}{r} x \frac{d}{dx} + \frac{m}{r} \right]^{n-r} \left[x \frac{d}{dx} \right]^r u = (n-1)^r \left[\frac{n}{r} x \frac{d}{dx} - \frac{m}{r} - 1 \right]^n x^r u,$$

in which the usual factorial notation

$$[a]^b = (a)(a-1) \dots (a-b+1)$$

is adopted. And the complete integral of this differential equation is

$$u = C_1 y_1^m + C_2 y_2^m \dots + C_n y_n^m,$$

$y_1, y_2, \dots, y_n$ being the n roots of the given algebraic equation. From this theorem, which is an extension of one given by the late Prof. Boole in the Philosophical Transactions for 1864, p. 735, all the differential resolvents of algebraic equations of the above trinomial form may be readily deduced, by making $m=1$, in which case $u=y$, and depressing the differential equation by immediate integration.

On Chasles's Method of Characteristics. By Professor T. A. HIRST, F.R.S.

After briefly explaining the nature and scope of this important method, by which the theory of conic sections has now been completed, the author communicated a few of the results of Professor Chasles's most recent researches on the properties of conics in space, which satisfy one less than the number (eight) of conditions necessary to determine them. These results were communicated to the Academy of Sciences, on September 4, 1865, and appear in the 'Comptes Rendus' of that date.

On Quadric Transformation. By Professor T. A. HIRST, F.R.S.

The object of the paper was to establish new properties of two figures (in one and the same plane) so related to one another that to a point in one figure corresponds but one point in the other, and *vice versa*, whilst to a right line in the one figure corresponds a conic section in the other. Among these properties were several which exhibit a remarkable connexion between a correspondence of this kind and

the theory of numbers. The author's attention was first directed to this connexion by Professor H. J. S. Smith, of Oxford.

On a Method of discovering Remainders in Arithmetical Division.

By C. M. INGLEBY, LL.D.

Let A be any number (or aggregation of units), and let the prefix R indicate the operation of distributing the number to which it is prefixed in a scale of notation whose radix is r . Let B be the number of units in RA; then *pariter* MB is the operation of distributing B in a scale whose radix is m ; and so of other prefixes.

Then $\frac{RA-MB}{r-m}$ is an integer, m being + or -. Now, if $MB > r$, let C be the number of units in it. Then $\frac{RA-MC}{r-m}$ is an integer; and so on until we arrive at

MT, a number $< r$. Then, finally, $\frac{RA-MT}{r-m}$ is an integer; $\frac{RA}{r-m}$ and $\frac{MT}{r-m}$ have equal remainders, and as $MT < r$, if +, it is either $r-m$, or is the remainder after dividing RA by $r-m$; and if MT is -, $r-m-MT$ is the remainder sought.

Apply this to the denary number 76438; then $r=10$.

(1) Let $m=1$, then the divisor is 9;

$$MA=8+3+4+6+7=28; MB=8+2=10; MC=1,$$

the remainder after dividing 76438 by 9. (This is an extension of the principle of "the rule for casting out the nines.")

(2) Let $m=-1$; then the divisor is 11;

$$MA=8-3+4-6+7=10; MB=-1; \text{and } 11-1,$$

or 10, is the remainder after dividing 76438 by 11.

(3) Let $m=-6$; then the divisor is 16;

$$MA=8-3 \times 6+4 \times 36-6 \times 216+7 \times 1296=7910;$$

$$MB=-6+9 \times 36-7 \times 216=-1194;$$

$$MC=-4+9 \times 6-36+216=230;$$

$$MD=-3 \times 6+2 \times 36=54;$$

$$ME=4-5 \times 6=-26;$$

$$MF=-6+2 \times 6=6,$$

the remainder after dividing 76438 by 16.

The theorems dependent on this general principle are as follows:—Writing SA for the ultimate operation on A instead of MT, and letting $A_1, A_2, A_3, \dots$ A_μ be μ numbers,

$$S(A_1.A_2.A_3 \dots A_\mu)=S(SA_1.SA_2.SA_3 \dots SA_\mu). \dots (1)$$

$$\text{Cor. If } A_1=A_2=\&c. \dots =A_\mu, SA_\mu=S(SA)_\mu \dots (2)$$

$$\text{Also } S(A_1+A_2+A_3+\dots+A_\mu)=S(SA_1+SA_2+SA_3+\dots+SA_\mu) \dots (3)$$

$$\begin{aligned} \text{Cor. } S(A_1^{m_1}+A_2^{m_2}+A_3^{m_3}+\dots+A_\mu^{m_\mu})^n \\ =S[(SA_1)^{m_1}+(SA_2)^{m_2}+(SA_3)^{m_3}+\dots+(SA_\mu)^{m_\mu}]^n \dots (4) \end{aligned}$$

P.S. If m be + and > 1 , and MT (or SA) $> m$, (it *must* be $< r$), we have apparently a case of failure.

On a New Method in Geometry. By Prof. PLÜCKER.

On the Extension of Taylor's Theorem by the Method of Derivations.
By Prof. PRICE.

On some Applications of the Theory of Probabilities. By Prof. PRICE.

*On the Calculation of the Potential of the Figure of the Earth.**By W. H. L. RUSSELL.*

The object of this paper was to simplify and render symmetrical certain portions of Professor O'Brien's investigations on the figure of the earth. In that paper the reduction of the expression for the potential to a convenient form is effected by the introduction of a discontinuous quantity; the author of the present paper has found that the required form is obtained much more shortly by dividing the original definite integral into two parts, and then expanding separately.

*On the application of D'Alembert's Principle to the Rotation of a Rigid Mass.**By Dr. STEVELLY.*

The author explained that the present method of applying D'Alembert's principle to the investigation of the spontaneous axis assumed by a free, rigid mass, under the action of force, in all the works he was acquainted with, led to what he showed to be a false conclusion, viz. that that axis must be a principal axis of the rigid mass. He showed how the error arose from neglecting, in applying the principle of D'Alembert, to take into account not only that part of the motion of each elementary part of the body which related to the *magnitude* of its motion, but also that part which relates to its *direction*, and from which its centrifugal endeavour at each instant arises. But if the force impressed tend to produce rotatory motion round an unstable spontaneous axis, how can the present mode of applying D'Alembert's principle lead to a true conclusion, when it proceeds on the method of bringing the body into such a state that the equations of equilibrium (that is, of no after-change) shall give the direction-courses of the axis?

*On a Special Class of Questions on the Theory of Probabilities.**By Professor SYLVESTER, F.R.S.*

After referring to the nature of geometrical or local probability in general, the author of the paper drew attention to a particular class of questions partaking of that character in which the condition whose probability is to be ascertained is one of pure form. The chance of three points within a circle or sphere being apices of an acute or obtuse-angled triangle, or of the quadrilateral formed by joining four points, taken arbitrarily within any assigned boundary, constituting a reentrant or convex quadrilateral, will serve as types of the class of questions in view. The general problem is that of determining the chance that a system of points, each with its own specific range, shall satisfy any prescribed condition of form. For instance, we may suppose two pairs of points to be limited respectively to segments of the same indefinite straight line: the chance of their anharmonic ratio being under or over any prescribed limit will belong to this category of questions, to which, provisionally, the author proposed to attach the name of form-probability. In questions of form-probability, in which all the ranges are either collinear segments or coplanar areas, or defined portions of space, rules may be given for transforming the data, so as to make the required probability depend on one or more probabilities of a simpler kind, leading to summations of an order inferior by two degrees to those required by the methods in ordinary use. Thus Mr. Woolhouse's question relating to the chance of a triangle within a circle or sphere being acute can be made to depend upon an easy simple integration, the solutions heretofore given of this problem involving complicated triple integrals. It was shown, as a further illustration, that the form-probability of a group of points all ranging over the same triangle remains unaltered when the range of one of them is limited to any side of the triangle chosen at will, and, again, (for convenience of expression distinguishing the contour into a base and two sides) will be the mean of the two probabilities resulting from limiting one point to range over either side with uniform probability, and simultaneously therewith a second point of the group over the base, with a probability varying as its distance from that end of the base in which it is met by the side. An analogous rule can be given for transforming the form-probability of a group limited to any the same parallelogram. So again for a group of points ranging over a plane figure bounded by any curvilinear contour.

The problem may be transformed by supposing two of the points of the group to range on the contour itself, according to a law which may be expressed by saying that the probability of their being found on any arc shall vary as the product of the segment included between the arc and its chord, multiplied by the time of describing the arc about any centre of force arbitrarily chosen within or upon the contour,—a theorem which, accepting the idea of negative probability, admits also of extension to the case of a centre of force exterior to the contour.

Among other problems which the author readily resolves by aid of his principle of transformation, may be mentioned that of determining the mean value of a triangle whose angles are taken at random anywhere within a given triangle, parallelogram, ellipse, or ellipsoid. In this description of questions a peculiar difficulty arises, from the fact that the figure which is to be integrated in order to determine the numerator of the fraction which gives its mean value must always be taken positive, whereas its algebraical expression will repeatedly change its sign, according to a more or less complicated law. This quality of the analytical exponent of the arithmetical value of the figure constitutes, in fact, a sort of polarization which has to be got rid of; and the depolarizing process is effected with great ease by virtue of the simplified form impressed upon the data by the method set forth in the paper.

The author further took occasion briefly to allude to the form in which his own problem of four and Mr. Woolhouse's problem of three points were originally proposed, viz. in each case without a specified boundary, and to express his opinion that the principle which had been applied to them, and in which he had formerly acquiesced, was erroneous, as it could be made to lead to contradictory conclusions, and must be abandoned. He was strongly inclined to believe that, under their original form, these questions do not admit of a determinate solution.

On Professor Price's Modification of Arbogast's Method.
By Professor SYLVESTER, F.R.S.

LIGHT.

On Moving Photographic Figures, illustrating some Phenomena of Vision connected with the Combination of the Stereoscope and the Phenakistoscope by means of Photography. By A. CLAUDET, F.R.S.

From the beginning of photography it must have struck those who were acquainted with the phenakistoscope, invented by Plateau, that photography could produce with advantage series of pictures for that instrument with greater accuracy than any made by hand. M. Duboseq made some ingenious attempts in this direction, but not entirely satisfactory. The author had also turned his attention towards the subject, and had practically experienced the difficulty of obtaining together the phenakistoscopic and stereoscopic effects. He desired to lay before the Association an attempt he had made some years ago, illustrated by an instrument showing how easy it was to obtain the illusion of moving figures, but without stereoscopic effect,—two pictures of different positions being sufficient to elicit the phenomenon, although the illusion suffers from the deficiency of intermediate positions. Nothing, however, is easier than to employ eight different pictures in as many different stages of the action, and the effect will be sufficiently complete. For this, Mr. Claudet, having placed in his stereoscope two separate cubic frames, has only to fix on their four sides, at right angles, two sets of four pictures, which are made to pass in consecutive order before the lenses, and the figure assumes consecutively eight different stages of the whole action. The instrument with only two pictures will suffice to illustrate the principle, and, at the same time, elicit some curious phenomena of the perception of vision. The author has constructed his instrument in such a manner that by means of a slide with one hole he can, by moving it rapidly in a reciprocating horizontal direction, shut one lens while the other remains open; and in continuing that motion, while one eye sees one of the two pictures,

the second eye cannot see the other picture. If, before the sensation of one eye exhausted, the slide shuts the first lens and opens the other, a new impression is produced, and we have an uninterrupted sensation of vision as if the object had moved before us; and if a sufficient number of pictures represent that object in the various consecutive positions it has assumed during the several stages of its motion, we experience the sensations we have when we see the object while moving; and although the pictures in their limited number do not show all the intermediate positions, still the mind has the power of filling up the deficiency, as it does if, when looking at a real object in motion, we accidentally wink the eyelids, or an obstacle happens to pass between us and the object. To exemplify this, Mr. Claudet has employed two photographic pictures, one representing the beginning of an action, the other the end. By moving the slide one way, the right eye can see the picture representing the figure in one position, while the picture showing the other is invisible to the left eye; then by moving the slide the other way, the left eye sees the figure in the second position, and the first picture is invisible to the right eye. Although we have really only seen the figure in two extreme positions, still we have the illusion of having observed the intermediate positions—as, for example, in a slide exhibited having one picture of a boxer with his arm close to his side as preparing to hit, and another with the arm extended delivering the blow. Here, although all the intermediate positions are omitted which must have been assumed during the act, the mind completes the action. Another curious phenomenon of this alternate vision is, that one cannot distinguish which eye the object is seen by; for although the vision is transferred alternately from one eye to the other, we are not conscious of the act; and during the change of pictures which has taken place in the meantime, we have had a uniform and uninterrupted sensation, and consequently it has appeared as if the object were moving.

On Spectacles for Divers, and on the Vision of Amphibious Animals.

By F. GALTON, F.R.S., F.G.S.

Bathers who have surmounted the very natural repugnance, felt by beginners, to open their eyes when they dive, find when they look about them under water that nothing is to be seen with distinctness. They perceive little more than a haze of diffused light; for their eyes are thoroughly out of focus in a water medium. When a man under water holds his hands at a little distance from his face, so great is the confusion of outline, that he cannot discover the spaces between his fingers even when he has separated them as widely as possible. The appearance is a formless blur of white. Now what is the precise cause of this indistinctness of vision? By what optical arrangement can it be overcome? And how do amphibious animals accommodate their sight to the requirements both of air and of water? Suppose a tube, with a flat bottom of glass, filled with water; when the surface is perfectly still, and we look down the tube, we see objects lying in the water and others in the air below the glass bottom, with perfect distinctness. But if we bend the head down to the tube, the instant the eye touches the water all distinctness of vision ceases. The convex surface of the eyeball has indented the plain surface of the water and thereby turned the tube into a concavo-plane water-lens. The convexity of the eyeball is very great; according to physiologists, the radius of its curvature is only 0.31 of an inch; the effect of the concave lens which it stamps on the surface of the water must be proportionately large; and if it be desired to counteract its influence, a convex lens must be used of such high power that, when immersed in water, its effect shall be equal and opposite to that of the concave water-lens. A simple calculation shows the description of lens required. A double-convex lens of flint glass, each of whose surfaces has a radius of 0.48, is the equivalent. It would exactly neutralize the effect of the concave water-lens, if it were held close to the eyeball. This curvature of the lens would require to be somewhat modified according to the convexity of each individual eye, and to the refractive power of different kinds of flint glass. When held at the usual distance of an eye-glass from the eye, a lens of more moderate power, such as a radius of 0.60, or even 0.70, is found sufficient. Furnished with eye-glasses containing suitable lenses, we might expect that the vision of a diver would be rendered as clear under water as in air, that its range would be limited only by the turbidity of the water, and that it would not be

affected by indistinctness due to the disordered focus. But the author had found that the eye, when looking through a lens of this description under water, has not much power of accommodating itself to different distances; and with the best of those the author had as yet constructed, the limit of distinct vision appeared practically restricted to a range of about eight feet. The attempt, however, was only provisional: his experiments had but very recently been commenced. It must be distinctly understood that men in diving-machines or helmets do not require such lenses; for their eyeballs are separated from the water by the apparatus in which they are cooped up. All that is needed by such persons is to have ordinary windows of stout plate glass through which they can look out into the medium which surrounds them. The author's contrivance refers to the wants of divers in pearl- and sponge-fisheries, to sailors who have occasion to examine the bottoms of their ships, to persons who have dropped something in the water which they wish to recover, and to bathers generally. To those who can swim, the author promises a material addition to their enjoyment, in the possession of these eye-glasses or spectacles. It is no slight pleasure to live in some degree the life of a mermaid, keeping below water for a minute at a time, and seeing everything in one's immediate neighbourhood as clearly as it could be seen by leaning over the gunwale of a boat on a still day, when the glare from the water was perfectly shaded. There are many amphibious animals that see as well under water as in air. Amongst these are seals, otters, hippopotami, water-rats, and diving birds of many descriptions. The cornea of the seal is flattened, but that of the other animals appears to be as convex as in man. By what means these other animals are able to adjust their eyes to the requirements of water and of air indifferently, is wholly unexplained. Physiologists do not seem to have been aware of the vast powers of optical adjustment which the habits of these animals necessitate.

The Refraction Equivalent of Carbon. By Dr. J. H. GLADSTONE, F.R.S.

The refractive index of a substance, minus unity, divided by the specific gravity, is termed its specific refractive energy; and this multiplied by the chemical equivalent has been termed, by Landolt, its refraction equivalent. The present communication was intended to shew that carbon, whether as the pure element, or as a part of solid, liquid, or gaseous compounds, has the same refraction equivalent, viz. 5, or a little more. Diamond gives 5; carbonic acid, 5.03; bisulphide of carbon, 5.3; chloride of carbon, 5.15; cyanogen, about 5.2; many hydrocarbons, 5; sugar, about 4.8; while Landolt, from the refraction equivalents of compounds differing by one equivalent of carbon, determined the number 5. In some highly dispersive substances a higher number was arrived at by calculation.

On a New Form of Spectrum-Microscope. By H. C. SORBY, F.R.S.

The superiority of this instrument, as compared with that first proposed by the author, consists in the employment of a compound direct-vision prism over the eye-piece. The slit is fixed in the focus of the upper lens of the eye-piece, which is made achromatic, so that all parts of the spectrum may be distinctly seen at the same time. By using a binocular microscope, the inclined tube can be employed as a finder; and on arranging so that a minute object is in the centre of the field, it will be directly in front of the slit fixed in the eye-piece of the other tube. On looking through this eye-piece it is easy to see that the object is properly placed in front of the slit; and then, on placing the prism on the eye-piece, as if it were a Nicol's prism, the spectrum of the object can be seen to great advantage. This compound analyzing prism consists of two right-angled prisms of flint glass, between which is a rectangular prism of crown glass, and at each end a crown-glass prism of about 75°, all cemented together with Canada balsam. Arrangements are also made in the instrument, by means of a reflecting prism covering half the slit, so that the spectrum of a minute object placed on the stage may be compared with that of a larger object placed on a stage attached to the side of the eye-piece, and thus their difference or identity may be seen at a glance. It is thus easy to compare the spectra of minute crystals and of their solutions, to study the spectra of small coloured blowpipe beads, and, in fact, accurately examine the nature of the light

transmitted through any minute coloured substances. By using a parabolic reflector attached to the object-glass, opaque bodies may be examined by reflected light; and, as a curious test-object, it may be mentioned that, by this means, a speck of blood on white paper, which would not weigh more than one-millionth of a grain, will show a perfectly characteristic spectrum.

HEAT.

Experimental Inquiry into the Laws of the Conduction of Heat in Bars, and into the Conducting-Power of Wrought Iron. By Principal FORBES, F.R.S.

The experiments described in this paper were all made in 1850 and 1851, upon a plan which was fully explained by the author in letters to Mr. Airy and Professor Kelland in the former year. Some notice of them appeared in the British Association Reports for 1851 and 1852, and the apparatus was supplied by a grant from the Association.

In previous inquiries into the thermal condition of a long conducting bar heated at one end, two assumptions have always been made:—*first*, that the flux of heat across any transverse section of the bar is proportional throughout to the rapidity of the decrement of temperature reckoned along the axis of the bar (or to $\frac{dv}{dx}$, where v represents the temperature, above that of surrounding space, of any point of the axis of the bar at a distance x from the origin) : *secondly*, that the loss of heat by radiation and convection from the surface of the bar is at every point proportional to the same temperature v . By assuming these principles (the last of which is certainly more or less inexact), the well-known solution of the problem of the heated bar is, that the temperatures (or excesses of temperature) diminish in a geometrical progression from the origin, and finally, of course, become insensible. Previous experimenters have confined themselves to finding the constants of the logarithmic curve for different substances, and thence their *relative* (not absolute) conducting-powers.

In the experiments now described, neither of the above-mentioned principles is assumed. The external loss of heat is *directly* ascertained by experiment, and the admissibility or otherwise of the first of the two assumptions is also *directly* tested.

That assumption may be thus symbolized: $F = -k \frac{dv}{dx}$, where F is the flux of heat across unit of section, k the conducting-power for the substance employed, and v and x have the same signification as before.

I. In the first instance, a bar of iron 8 feet long and $1\frac{1}{4}$ inch in diameter, was heated at one end by means of a crucible containing melted solder. Thermometers were inserted at various points of its length. The results, v in terms of x , were projected in a curve (approximately a logarithmic), and the values of $\frac{dv}{dx}$ were found by projection or calculation, or both.

II. Next, a short bar (20 inches long), perfectly similar in section and condition of surface to the long bar, is heated to above 200° Cent. in a bath of fused metal, and allowed to cool in free space, a thermometer being inserted at the centre of its length. This gives us the rate at which such a bar is parting with its heat from all causes whatever, in terms of the temperature shown by a thermometer in its axis.

III. The losses of heat in unit of time (one minute) last found, may be taken as representing the amount of heat dissipated from each elementary section of the long bar in the statical experiment (I.), being given in terms of the temperature proper to each point of such a bar. A curve may thus be constructed, having for its line of abscissæ the axis of the long bar, and for ordinates, the rate of dissipation of heat from each portion of its surface due to both radiation and convection. This curve is called by the author *the statical curve of cooling*.

IV. If we can by mechanical quadrature, or otherwise, find the whole amount of heat dissipated between any point of the long bar and its coolest extremity, we

have, in fact, the flux of heat passing from the hotter extremity of the body across the particular section in question; for the condition of permanence of the temperature of the bar arises from the equality of the heat supplied and dissipated. But the whole heat dissipated in unit of time is the integral of the partial dissipations represented by vertical ordinates of the last-named curve, taken between any assumed point x and the furthest or cool end of the bar. This quantity, then, is F or the flux across unit of section at the point x .

V. We are now able to resolve the question whether or not the flux of heat is in the given bar everywhere proportional to the rapidity with which the temperature decreases as x increases, or whether the equation holds, $F = -k \frac{dv}{dx}$, the conducting-power k being supposed to be constant.

The following Table shows that the constancy of k in the case of iron cannot be assumed,—on the contrary, that the conductivity diminishes when the temperature increases.

| Temperature,
Centigrade. | Conductivity of Wrought Iron. | |
|-----------------------------|---|---|
| | Units the Foot,
Minute,
and Cent. Degree. | Units the Centi-
mètre, Minute, and
Cent. Degree. |
| 0° | ·01337 | 12·42 |
| 50 | ·01144 | 10·63 |
| 100 | ·01012 | 9·40 |
| 150 | ·00934 | 8·68 |
| 200 | ·00876 | 8·14 |
| 250 | ·00826 | 7·67 |

The author had pointed out so long ago as in 1833 the apparent coincidence of the order of metals, taken with reference to their power of conducting heat and electricity. In 1852 he announced that the conductivity of iron for heat diminished with the temperature. Since that time Dr. Matthiessen has clearly established the same result for electricity, and finds, moreover, that the temperature-coefficient varies most rapidly at lower temperatures—a law which may be observed also to hold in the preceding Table for Heat. It would be premature to assert from these experiments alone that the “percentage decrement” in the case of iron is the same for heat and electricity, although it is not impossible that it may turn out to be so.

On the Second Law of Thermodynamics.*

By W. J. MACQUORN RANKINE, F.R.S.

It has long been established that all the known relations between heat and mechanical energy are summed up in two laws, called respectively the first law and the second law of thermodynamics, viz.:—First Law: Quantities of heat and of mechanical energy are convertible, at the rate very nearly of 772 foot-pounds to the British unit, or 424 kilogrammetres to the French unit of heat. Second Law: The quantity of energy which is converted from one of those forms to the other during a given change of dimensions and condition in a given body is the product of the absolute temperature into a function of that change and of the kind and arrangement of the matter of the body. By *absolute temperature* is here to be understood temperature measured according to a scale so graduated that the temperature of a homogeneous body shall vary in the simple proportion of the quantity of energy it possesses in the form of sensible or thermometric heat. The laws of thermodynamics as here stated are simply the condensed expression of the facts of experiment. But they are also capable of being viewed as the consequences of the supposition that the condition of bodies which accompanies the phenomena of sensible heat consists in some kind of motion amongst their particles. The first

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law would obviously follow from the supposition of any kind of molecular motion whatsoever, and it therefore affords of itself no reason for preferring one supposition as to the kind of molecular motion which constitutes sensible heat to another. But if there be molecular motions in bodies, it is certain that, although all of them are capable of conversion into that which constitutes sensible heat, some of them are not accompanied by sensible heat. For example, the motion, supposed to be vibratory and wave-like, which constitutes radiance, whether visible or invisible, is not accompanied by sensible heat, and only produces sensible heat by its absorption, that is, in the language of hypothesis, by its conversion into some other kind of motion; while, on the other hand, in the production of radiance sensible heat disappears. The object of the paper, then, is to give an elementary proof of the proposition (of which the author gave an intricate algebraical demonstration in the Transactions of the Royal Society of Edinburgh for 1851), that the second law of thermodynamics follows from the supposition that sensible heat consists in any kind of steady molecular motion within limited spaces. Steady motion may be defined as motion in a set of streams of invariable figure. When steady motion takes place in matter that is confined within a limited space, the streams in which the particles move must necessarily return into themselves, and be circulating streams, being, in that respect, of the nature of whirls or vortices. Steady motion keeps unaltered the distribution of the density of the moving matter; and it therefore keeps unaltered the forces depending on such distribution whether of the nature of pressure or of attraction. In this respect it differs from unsteady motion, such as vibratory and wave-like motion. Supposing that the dimensions of the limited space in which the moving matter is enclosed undergo an indefinitely small change by the application of suitable forces, and that after that process the motion becomes steady as it was before, then the dimensions and position of each circulating stream will have been altered, and the work done in effecting that alteration will consist of energy converted between the forms of potential energy of the applied forces and actual energy of the molecular motions—that is, between the forms of mechanical energy and heat. Prof. Rankine then works out the problem to this conclusion—that, if sensible heat consists in any kind of steady molecular motion within limited spaces, the conversion of energy during any change in the dimensions of such spaces is the product of the absolute temperature into some function of that change and of the sort and distribution of the matter. It is obvious that the *steadiness* of the supposed molecular motion is the essential condition which makes the second law of thermodynamics deducible from a mechanical hypothesis, and that no kind of unsteady motion, such as vibratory or wave-like motion, would lead to the same results. If then it be admitted as probable that the phenomena of heat are due to unseen molecular motions, it must also be admitted that, while the motions which constitute radiance are vibratory and wave-like, the motions which constitute sensible or thermometric heat must be steady, and like those of circulating streams. The function by which the absolute temperature is multiplied in calculating the conversion of energy between the mechanical and the thermic forms is the variation of what the author has called the “metamorphic function,” being one term of the differential of the “thermodynamic function,” which corresponds to what Prof. Clausius calls “entropy.”

ELECTRICITY.

On India-Rubber and Gutta Percha as Insulators for Submarine Telegraphic Cables. By W. FAIRBAIRN, F.R.S.

Mr. Fairbairn stated as his opinion that gutta percha, although not so perfect an insulator as india-rubber, was nevertheless preferable for deep-sea cables subjected to great pressure. He found by experiment that the conductivity of the core was improved by gutta-percha insulation under severe pressure to a greater extent than by india-rubber or any other insulating material; and he believed it was more durable and better calculated to resist the action of salt water at great depths.

Out of a great number of specimens of different kinds of insulators, he found that gutta percha, with the exception of Chatterton's compound, absorbed less water under a pressure of 20,000 lbs. on the square inch than any of the others, and that it closed much tighter upon the conducting wires than any of the other materials experimented upon.

As regards the 'Great Eastern' ship and the paying-out machinery, he went in her from the Nore to Valentia for the purpose of witnessing the behaviour of that vessel, and nothing could be more satisfactory than the 'Great Eastern' as a submerger. Her smooth and easy motion at sea, and the efficiency of the paying-out machinery, were in every respect calculated to ensure success; and it was much to be regretted that this important enterprise had failed from causes over which the parties engaged had probably no control.

On the Change of Form and Colour which the Stratified Discharge assumes when a Varied Resistance is introduced in the Circuit of an Extended Series of the Voltaic Battery. By J. P. GASSIOT, V.P.R.S.

Some months since the author commenced the construction of a voltaic battery, consisting of 4000 insulated glass cells, into each of which, in lieu of sulphate of copper, as used by the late Prof. Daniell, about a tablespoonful of sulphate of mercury is introduced; the elements carbon and amalgamated zinc plates are then inserted, and the cells filled with rain-water. In this form of battery the zinc plates apparently remain free from local action, and are consequently not oxidized or acted upon, except when the circuit is completed. When the battery is in action, sulphate of zinc is obtained in solution, and the mercury that is set free assists in the amalgamation of the zinc plates: the water being so slightly acidulated, and the resistance in the carbon plates being so much greater than if this element of the battery had been a metal, the amount of chemical action, and that of the electrical force, is proportionally less than that in the nitric-acid battery; but the discharge is constant and regular in a most remarkable degree. For his researches upon electric stratified discharges the author has now more than four hundred vacuum-tubes, some exhausted by himself, and others by Geissler, of Bonn. In one of the latter he obtained certain phenomena which it was the more immediate object of this communication to describe. The appearances in the tube, with discharges from 1200 and 4000 series of the battery taking place, and when the resistance of various lengths of a column of distilled water is introduced into the circuit, were illustrated by diagrams. The water is contained in a tube half an inch in diameter, and three feet long; two wires are introduced into it, one being connected with one terminal of the battery, and the other with the vacuum-tube; while by raising or lowering either of the wires the length of the column of water remaining in the current is increased or diminished, and in this way the amount of resistance can be altered with great facility. When one wire is inserted in the water, and the other touches the moistened surface of the glass, but is not in actual contact with the water, a luminous discharge will be observed, filling the entire tube, without any sign or appearance of stratification. On depressing the wire, and thus bringing it into contact with the surface of the water, small crescent-shaped disks of red light are observed to be rapidly produced in quick succession from the positive pole. On shortening the resistance by further depression of the wire, the disks commence receding, one by one disappearing at the positive terminal, until nineteen remain, much increased in brilliancy and definition. From this condition of the discharge a remarkable change takes place on further depressing the wire and reducing the resistance; the two disks nearest the negative terminal join together, assuming the form of a double-convex lens, the side facing the negative being of a slightly blue tinge, that towards the positive of a reddish fawn, and the centre a brilliant red colour. At the instant this change of form and colour takes place in the two disks, another crescent-shaped disk simultaneously appears at the positive terminal; and as the depression of the wire in the water is continued, each of the two disks nearest the negative terminal will successively join, and assume the double-convex form described, at every such change another crescent-shaped disk simultaneously appearing. When the circuit is completed without any resistance of water being

introduced in the current, all the nineteen striae assume the double-convex form, the blue being far more intense or vivid, particularly in those nearest the negative, the red line in the centre continuing in all. In this state of the discharge the tube was placed between the poles of a very powerful electro-magnet; and on exciting the magnet the disks separated, precisely as if a resistance had been introduced, but deflected to the upper or lower part of the tube, according to the direction of the magnetic power. On the sides of the tube, where four or five of the disks nearest the negative impinge, there at present remains a black deposit similar to that deposited from the negative metallic wires by an induction-coil. As much heat is evolved at the negative wire, and until the author obtains another tube which will exhibit the same results he does not like to risk its destruction, he is thus prevented from continuing the experiment to the extent he desires: but if it is found that a deposit can be obtained at defined portions of the stratified discharge, it may probably assist in explaining phenomena which have hitherto baffled the researches of every electrician.

On a New Method, introduced by Messrs. Siemens, for the Measurement of Electrical Resistances. By R. SABINE.

The insulation of submarine-telegraph cables was, until the Red-Sea and Indian lines were submerged, in 1859, determined qualitatively by the simple deflection of a galvanometer-needle. The manufacture of the core of the Malta cable, with the scrupulous surveillance of its electrical conditions, formed an era in cable-work; and Messrs. Siemens, who were intrusted by the Government with the duties of electricians to the cable, may be said to have then first established with success the science of cable-testing. After various improved plans, the Messrs. Siemens introduced, in 1860, for cable-work, a differential galvanometer with two coils, one of which exerted two thousand times as much deflective force upon the needle as the other. The cable and the measuring-battery were inserted in the circuit of the larger helix, and a single element with a set of resistance-coils in that of the less sensitive helix of the instrument. The resistance in the latter circuit was altered until the magnetic forces of the two currents upon the needle were equal and opposite and the pointer rested over the zero-line of the card. The manipulation was simple, and the necessary calculations reduced to the mere multiplication of the value of the resistance in the smaller circuit by the constant of sensibility and the relation of the electromotive forces. On the fitting out of the Carthage cable it was considered desirable in measurements of insulation to dispense with mathematical reductions, and to read off the resistances directly from the instrument. It is easily understood that, to establish an equilibrium between the magnetic forces of two coils of a differential galvanometer, it is not absolutely necessary to alter the currents in either of the circuits; the same may be attained by *altering the relative distances* of the coils from the needle. This is the principle upon which the new differential galvanometer, forming the subject of this communication, was based. The mechanical construction of the instrument is very simple. A pair of astatic needles are suspended by a fibre of unspun silk between about 10,000 turns of a long, thin, well-insulated copper wire, their position being indicated by an aluminium pointer fixed across their axis, moving over a dial-card and observed through a magnifying-glass. Outside the case of the instrument is a horizontal metal stage, upon which a vertical coil of insulated copper wire is moved to and from the instrument by means of a micrometer screw. The theory of the method of this instrument and its use in testing cable resistances is this:—Two galvanic currents circulate in the two coils—the stationary and the moveable—in opposite directions, and will oppose each other in their effects upon the needle, which will take up a position at an angle less than that which it would if the stronger coil were alone active. By altering the position of one of the coils a point is reached where the deflective force of one coil is made to exactly counterbalance the force of the other, and the needle returns to zero. To measure the resistance of a cable with this instrument, then, nothing more is necessary than to put it in the circuit of the larger coil and to vary, by means of the micrometer-screw, the position of the moveable coil until equilibrium is obtained. The distance is then

read off, and a table prepared beforehand supplies the corresponding resistance in units. In this way, during the paying out of a cable, the state of the line can at any time be known without expending time in calculating the observations.

On some New Arrangements of the Poles of Magnets. By Capt. SELWYN.

The author described a method by which magnets may be made of which both ends possess north polarity or south polarity at will; and under these circumstances the place of both the south or both the north poles will be found in close juxtaposition in the centre of the bar. The process by which these effects are produced is to take out the temper of the bar, at any point where it is desired the two poles shall be in proximity, by a rod of heated metal or by the blowpipe. This operation, while seemingly leaving the bar intact, has separated the two magnets, though the ends will still be respectively north and south poles. If now the north pole of a strong magnet be used and drawn from the centre of the bar towards the north end of the prepared needle, the polarity of that half will be reversed without affecting the other end, and by a series of careful touches both ends will become equally balanced south poles, as in a specimen exhibited to the Section. If the bar has been softened in more than one place, a series of magnets may be produced in the same piece of steel with similar or dissimilar poles in juxtaposition.

Capt. Selwyn also exhibited and described to the Section a new form of horizontal galvanometer, compensated by the introduction of a natural fixed magnet, in addition to the moveable one which is deflected by the current of electricity in these instruments. This is kept at zero by the attraction of the first, and its force is exerted in opposition to that of the current of electricity, and in a similar ratio.

METEOROLOGY.

Remarks upon Aërial Navigation, suggested by Mr. GLAISHER's late Balloon Ascents. By F. W. BREAREY.

Mr. Brearey, alluding to the important observations of Mr. Glaisher, remarked that he had only been creeping along the borders of a vast immensity of which we know almost nothing.

Now that public attention was directed to these scientific efforts, and that the balloon was becoming more than a toy, he would at once propose the formation of a society, to be supported by subscriptions and donations, by which experiments could be conducted in its own grounds, and with its own apparatus, for the furtherance of investigations in aërology and aërial locomotion.

After pointing out the requirements of aëronauts for locomotive purposes, Mr. Brearey suggested, with the object of saving gas and ballast, that a man might raise himself in the air by a mechanical appliance attached to a balloon inflated only to such an extent as would give him buoyancy. The downward blow of paddles made of bamboo and silk, if returning feathered for each succeeding stroke, would enable him to effect this, and also to keep a low elevation, go with the wind, ascend and descend at pleasure, find different currents, and save his gas for future use.

It would, moreover, comply with the conditions insisted upon by late writers on aëronautics, viz. "that, to contend with the air, one must be specifically heavier than the air."

On the Great Storm of December 1864, on the Coast of the Peninsula.
By J. B. CAPELLO.

On the Heat attained by the Moon under Solar Radiation.
By J. PARK HARRISON, M.A.

On the assumption that the moon's crust is constituted geologically like the earth, 1865.

different parts of her surface would not attain the same degree of heat. Nearly two-thirds of the hemisphere turned towards us is honeycombed with gigantic craters, and covered with the débris of stupendous volcanic eruptions, the region in which Tycho is situated forming a principal part of the whole extent, and being conspicuous to the naked eye from its superior brightness. That region should therefore absorb less heat in proportion to its reflecting properties. On the other hand, the dark surfaces of the moon would absorb and radiate heat in the inverse ratio to their non-reflecting properties. The above facts must be borne in mind in considering the question of the heat attained by the moon at the periods of opposition and quadrature. In addition to this, though the whole surface of the moon is exposed in turn for from about thirteen to rather more than sixteen days to the solar rays, in speaking of the heat which our satellite attains it must not be considered that equal surfaces illuminated—*e. g.*, at the first and third quarters—are *equally heated* because so illuminated, or without reference to the duration of the sun's radiation upon them. On the contrary, at the day of first quarter, the region of the moon which has received the rays of the sun for a mean period of rather more than four days, after being subjected to the most intense cold during the moon's long night, has been but very little warmed up to the completion of the first quarter; the region opposite the earth having received the heat of the sun's rays for only about four-and-twenty hours—a period manifestly insufficient for any surplus heat to have been absorbed, even if the region had been favourable for storing radiant heat. At the period of last quarter, on the other hand, the surface illuminated will have been heated thrice as long as at the first quarter, namely, for a mean duration of eleven days; and not only so, but at the time when the moon completes her third or "last quarter," a similar surface to that at first quarter will have received the heat of the sun's rays for 360 in place of 24 hours,—with this additional peculiarity, that the surface generally will be a good absorber of heat. The heat of the moon at the last quarter might, on like grounds, be shown to be greater, or certainly not less, than at the full. It will be sufficient, however, to point out that the portion of the moon's fully-illuminated hemisphere opposite to us, and which radiates heat directly towards the earth, is not heated so intensely at the full as at the last quarter, or for a day or so after that phase; the ratio in favour of the latter period being nearly two to one, whilst the ratio in favour of the last quarter, compared with a corresponding region in the first quarter, is rather more than fifteen to one; the measure being the duration of solar radiation, without reference to the dark or light surfaces on which it falls.

The author exhibited a curve of the mean temperature at Greenwich for fifty years*, showing that the period of the greatest heat of the lunar surface synchronized with the period of greatest [average] monthly cold in the terrestrial atmosphere, and conversely.

On the Self-Registering Barometer at the Liverpool Observatory.

By ALFRED KING, M.I.C.E.

The increased attention given of late to meteorological observations has naturally created a demand for instruments, which, by their own action, shall produce a permanent record of the various phenomena of our atmosphere. Photography requires considerable skill in the manipulation, and a more direct and simple mode of self-registration is therefore in some cases a desideratum. The instrument described in this paper is a *floating* barometer, constructed by Mr. King, since the exhibition of the first trial instrument at a former Meeting of the British Association in 1854. In the ordinary barometer the variations in the atmospheric pressure are indicated by the varying height of a column of mercury within a tube; in this floating barometer they are made evident by the movements of the tube itself, which is counterpoised by a weight, say at 29 inches. If by the increase in atmospheric pressure the length of the column of mercury in it is increased to 30 inches, it is evident the equilibrium will be destroyed, and the weight of the additional inch of mercury will cause the tube to descend. If, on the other hand, the pressure is reduced to 28 inches, one inch of mercury in the column will be lost,

* See curve for 43 years, Report 1859.

and the tube will rise. The indications of the instrument being dependent on the motion of the suspended tube, by the contrivance of a partially immersed annular float surrounding its lower end, the displacement of a corresponding bulk of mercury in the cistern compensates for the gain or loss of weight in the tube. The range of the index is determined by the proportion which the area of this float bears to that of the tube. The tube at the Observatory is 3 inches in diameter, and the range $5\frac{1}{2}$ times that of the ordinary barometer.

On an Anemometer for the Registration of Cyclones or other Tropical Hurricanes. By A. FOLLETT OSLER, F.R.S.

The anemometers erected in this country, though capable of registering the storms of these latitudes, are not found equal to withstanding the force of a tropical hurricane. To strengthen the parts sufficiently would cause them to be too ponderous: the momentum obtained by so much additional matter put in rapid motion would produce fallacious results. In the instrument proposed, of which models of the various parts were exhibited, the pressure-plate is not exposed to the direct action of the wind, but is placed in a horizontal position in a circular box, somewhat resembling the form of a cheese, which being edgewise to the current offers much less resistance to the force of the hurricane. A long flat aperture near the bottom of the box is kept facing the wind by means of a vane, and the horizontal pressure-plate, which is carried by strong springs, has an air-tight diaphragm round it connecting it with the inside of the box; the force of the air entering by the long apertures and thus impounded in the box, is measured by the amount of motion communicated to the plate, and is recorded by a simple contrivance which is connected by a wire with the pressure-plate, and dots off the maximum and minimum force of each gust either on plain paper or, as recommended by Mr. Osler, on double sheets with carbon paper between, so as to obtain duplicate records, the paper being carried forward in the usual way by means of a clock. The trouble and uncertainty of pencils for recording the force of the wind is, by this plan of dotting, entirely removed; the point which makes the dot moves without touching the paper, and is brought down by a double knee-joint to make the dot only when the maximum or minimum pressure has been attained.

The direction of the wind is at the same time recorded by connecting with the vane two endless crank or bell chains, carried by two pulleys, the centres of which are placed at a distance from one another equal to the range that may be desired for making the record; to these chains, which work parallel to one another, the recording pencils or styles are attached: the movement is simple, and not easily deranged. Mr. Osler also exhibited a model of a small portable observatory arranged for this instrument; it is circular, about seven feet high, and tapering from three feet six inches in diameter at the bottom to three feet at the top, and divided perpendicularly into four parts for portability. A strong iron hoop fits over each end, to which iron rods are fixed as guys, stretching out in four directions to iron or wood posts let firmly into the ground. The principal advantage of this construction consists in its capability of being temporarily but securely fixed in any situation that may be desirable for special anemometrical observations.

On the Anomalies of our Climate. By T. L. PLANT.

In this paper the author pointed out the extremes which had come under his observation in Birmingham during twenty-nine years, *i. e.* from 1836 to 1864.

On the Meteorology of Birmingham. By D. SMITH.

The results given in this paper were deduced from observations extending over a period of twelve years, namely, from 1853 to 1864 inclusive, and as far as could be the records thus obtained were compared with the results of the medical inspections of the borough. The weekly Returns of the Registrar-General of Births and Deaths, and the meteorological returns of eleven large towns by Mr. Glaisher, which accompany it, reveal facts of the highest interest, affording, as they do, a comparison of death-rates with temperature. But the author considered there was yet re-

quired in every large town, especially in Birmingham itself, the population of which is increasing at the rate of about 5000 yearly, a distinct record of the new cases of disease, the nature of the localities in which they have occurred, and the conditions of atmosphere under which they have been formed. The principal local results obtained are—Mean atmospheric pressure (reduced to sea-level), 29·958 inches; mean temperature, 47°·6; the highest temperature, 89°·2; the lowest mean, -2°·5; mean yearly rainfall, 27·991 inches; greatest fall, 35·16; least, 21·21; mean number of days on which rain fell, 176.

Description of the Magnetic Storm of the Beginning of August 1865, as recorded by the Self-recording Magnetographs at the Kew and Lisbon Observatories. By J. B. CAPELLO and B. STEWART, F.R.S.

The great magnetic storm which broke out about the beginning of August last will be remembered as occurring at the time when anxiety began to be felt respecting the fate of the Atlantic cable. The following are the general characteristics of that storm, and apply both to Kew and Lisbon, since these two places were similarly affected by the storm. It first commenced about 5.40 p.m. (G. M. T.) of the 2nd of August; but it broke out with great violence, and with those rapid motions which form the mark of a large disturbance, about 5 a.m. of the 3rd of August, and this outbreak lasted until midnight of that day or early morning of the 4th of August. The disturbance then ceased for about twenty-four hours, recommencing a little before midnight of the 4th of August, and lasting till about 4 p.m. of the next day. There remained, however, traces of the disturbance for a considerable time after this date. There were thus two great outbreaks forming this storm, the first commencing on the 2nd of August at 5.40 p.m., or more notably on the 3rd of August, at 5 a.m., and lasting till early morning of the 4th of August, the second commencing about 11 p.m. of the 4th of August and lasting till 4 p.m. of the 5th of August. With regard to the first of these two outbreaks, from about 5 a.m. until 11 a.m. on the 3rd of August the horizontal and vertical components of the magnetic force were both considerably decreased by it, while in the afternoon of the same day they were both, but especially the vertical-force component, considerably increased. The westerly declination, on the other hand, was, on an average, increased during the greater part of this outbreak, although towards the end it was probably diminished. Broadly viewed, this disturbance may be said to have begun with a tendency to diminish both components of the force and to increase the westerly declination, and to have ended with a tendency to increase both components, but especially the vertical force. On the whole, the effect of the disturbance was, probably, to diminish both components of the force, and to increase the declination. With regard to the second of the two outbreaks which together constituted this storm, it began by diminishing both components of the force, if we except a comparatively small increase of horizontal force at the very commencement, and ended by slightly increasing both components at Kew. With respect to the westerly declination, this element was at first somewhat diminished, but it was ultimately increased by this disturbance. Broadly viewed, the characteristics of this second outbreak were similar to those of the first, exhibiting a tendency to diminish both components of force, and slightly to increase the declination. In comparing the storm with the greater one of August-September 1859, as registered at Kew, we find the following points of resemblance:—1. Both storms consisted of two separate outbreaks, and both the outbreaks of both the storms began during the hours of night or early morning. Thus we have—

| Storm of Aug.-Sept. 1859. | | Storm of August 1865. | |
|---------------------------|------------------|-----------------------|----------------|
| 1st Outbreak | 28 Aug. 10½ P.M. | 1st Outbreak | 3 Aug. 5 A.M. |
| 2nd do. | 2 Sept. 5 A.M. | 2nd do. | 4 Aug. 11 P.M. |

—2. Both outbreaks of both storms tended at first to diminish both components of the force, and to increase the westerly declination, but changed in the afternoon of next day into forces tending rather to increase both components. This is a very good instance of the influence (proved to exist by Gen. Sabine) of the hour of the day upon the character of the disturbance. Thus we see that in all these cases we have, in the early morning hours, a diminution of both components of the

force, while in the afternoon hours we have an increase of these components. 3. Both outbreaks of both storms tended, on the whole, to diminish both components of the force, and to increase the westerly declination,—a somewhat uncommon type of disturbance. 4. Both these storms were accompanied by phenomena on the surface of the sun which are worthy of notice. At the time of the occurrence of the great disturbance of August–September 1859, a very large spot might have been observed on the disk of our luminary, and several of a size somewhat smaller. Considerable changes were taking place in the appearance of these spots, and, moreover, a luminous body was observed, by Carrington and Hodgson independently, to move across the large spot at the very moment when the magnetic disturbance broke out at Kew. On the 29th of July, 1865, there was no spot or almost none on the sun's disc; but on the 3rd of August there was a very considerable spot on the right limb, nearly going off. The only pictures obtained at Kew were on these days, and it is clear from these that this spot must have rapidly formed between July 29 and August 3, on the right half of the solar disk. It would, of course, be premature to conclude that certain changes going on in the sun cause, or even invariably accompany, terrestrial magnetic storms; but there can be no impropriety in stating facts which may possibly serve to establish some future generalization.

An Improved Standard Barometer. By W. SYMONS.

At the Newcastle Meeting of the Association, the author exhibited a Standard Barometer combining the advantages of Fortin's and Gay-Lussac's instruments. The objection that the contraction and bending of the tube necessary in the arrangement for making that instrument portable impaired its sensitiveness, has been entirely removed in this improved one. The facility of reading is also increased.

HYDROSTATICS:

On the Hydrometer and its Adaptation to the present requirements of the Board of Inland Revenue. By L. OERTLING.

In this paper the means adopted for levying the duty upon spirits in the Revenue departments were considered, and attention called to the shortcomings of the present method. The instrument now used is Sikes's hydrometer, accompanied by Sikes's tables. It was distinctly pointed out that the instrument and the tables had been constructed upon different formulæ, and were not in harmony, and that, further, there were defects in the actual form of that hydrometer, causing considerable amounts of error in the estimation of the strength of the spirits tested by it.

INSTRUMENTS.

On a Self-recording Anemometer. By S. B. HOWLETT.

On the Topograph, a new Surveying Instrument By Captain LENDY.

The topograph may be used—

1. As a prismatic compass alone;
2. As a plane table alone with its sight ruler;
3. As a plane table and a compass, combined to facilitate the finding of stations.

It possesses the great advantage that it may be employed without any alteration, *simultaneously* or *successively*, as a plane table or a compass, when in the same survey we pass from undulating ground to open country, and *vice versa*. In all cases, we need no scales, no pair of compasses, and no protractor, the machine itself protracting the angles and laying down distances at the scale.

Again, the topograph may be used—

1. As a level;
2. As a clinometer, to obtain angles of elevation or depression, to find the difference of altitudes of two stations, and to lay down contours.

The object of the topograph is to enable anyone, however unacquainted he may be with mathematics, to become in a few minutes capable of surveying a road, sketching a country, finding the heights of buildings and mountains, &c ; to enable those who already possess a knowledge of surveying to survey almost as rapidly as they walk ; finally, to enable those who are acquainted with geometry to represent with accuracy the features of the ground in whatever districts they may find themselves. It is manufactured by Mr. Adie, 395 Strand.

On an Instrument by which any Rainbow that can possibly appear within the area of any picture, may be indicated in its right place and of the true size.

By CORNELIUS VARLEY.

CHEMISTRY.

*Address by Professor W. A. MILLER, M.D., LL.D., Treas. & F.P.R.S., P.C.S.,
President of the Section.*

INTERESTING historical associations are naturally awakened in the mind of the chemist as he enters upon the business of this section of our scientific gathering in the town whose hospitalities we are now sharing ; for he is reminded that on the 1st of August 1774, only ninety-one years ago, Priestley laid, at Birmingham, the foundation of modern chemistry, by the discovery of OXYGEN.

Yet it seems difficult to realize the fact that there must be some still living, who entered life when the chemical nature of the atmosphere was undiscovered, when water was believed to be an elementary substance, when the composition of the ordinary acids, nitric, hydrochloric, and acetic, was unknown, when the discoveries of Galvani had not been made, and when the battery which perpetuates the name of Volta did not exist.

It requires a considerable mental effort to estimate aright the extraordinary progress which chemistry, both in its scientific and in its practical aspect, has made since that day.

For example, the development of the laws of combination—the determination of the equivalent proportions of the elementary bodies—the art of chemical analysis—the Atomic theory—the isolation of potassium, with the consequent discovery of the compound nature of the alkalis and earths—and the marvellous developments of the organic department of chemistry, exhibit some of the most striking points in the progress of the science ; whilst in the chemical arts we may mention gas-lighting—the manufacture of stearic acid and other fatty acids for candles—the industry of petroleum and paraffin—the chemical process of bleaching by chlorine—the preparation of carbonate of soda from common salt, and the extensive alkali trade. The discovery of iodine and bromine, and their varied applications as remedial agents and otherwise—the fascinating processes of photography—the development of the trade in beet-root sugar—the extraction of quinia, morphia, and all the vegetable bases,—these and other processes of chemical manufacture too numerous to mention are all subsequent to, and may be said to be in nearly every case consequent on, the great discovery of oxygen.

Well may we sympathize, now, in the sanguine anticipations of Priestley himself, expressed in the preface to the volume in which this discovery is recorded, ‘Experiments and Observations on different Kinds of Air,’ vol. ii. p. vii :—“In reality, this is not now a business of air only, as it was at the first ; but appears to be of much greater magnitude and extent, so as to diffuse light upon the most *general principles* of natural knowledge, and especially those about which *chemistry* is particularly conversant. And it will not be now thought very assuming to say, that, by working in a tub of water, or a basin of quicksilver, we may perhaps discover principles of

more extensive influence than even that of *gravity* itself, the discovery of which, in its full extent, contributed so much to immortalize the name of Newton."

But it is not alone with the name of Priestley that we associate the progress of chemistry in Birmingham. Grouped around the father of pneumatic chemistry were several remarkable men who then either resided at Birmingham or frequently met there, including Matthew Boulton, James Keir, Dr. Withering, Dr. Darwin, and, foremost of them all, James Watt, who here diversified his engineering labours with his famous investigations into the composition of water. It was at the factory at Soho, too, that Murdoch made the first great experiment on gas-lighting, at the illuminations for the short-lived peace of Amiens; and it was in Birmingham that Dr. Roebuck, in the middle of the last century, erected the first leaden chamber for the making of sulphuric acid, and thereby inaugurated the most important of the chemical manufactures of this country.

Nor has Birmingham failed in more modern times to maintain her reputation in connexion with the chemical arts. Here, twenty-five years ago, Elkington founded the first establishment, in this country, for carrying out the processes of electro-plating and electro-gilding. Here Askin made the nickel of commerce, with its companion metal, cobalt, as oxide—articles that might vie in purity with the products of the laboratory. Here Chance has established a manufactory of optical glass, which specially calls for acknowledgment on the part of the student of science; and here Sturge and Albright have erected the only manufactory for red phosphorus which the country contains.

Vast as is the modern development of experimental science, it yet cannot excite much surprise that, with the exception of that portion which falls within the domain of the mathematician, science until recently has been systematically excluded from the general course of education, and has been followed in the majority of instances by those only who commenced its study for professional objects. Yet can we wonder at this, when we remember that the science of chemistry and many entire branches of experimental physics, including voltaic electricity, electro-magnetism, thermo-electricity, the phenomena of polarized light, of photo-chemical action, radiant heat, and others, are, as already stated, less than a century old? But the great strides that they have made in that interval, the social changes that they have introduced, and the additional powers that they have conferred upon man will vindicate their importance as necessary branches of knowledge to be acquired; whilst the more just appreciation of the methods of investigation which they pursue will establish their claim to be regarded as instruments in training the mind, and shaping the intellectual development of the future.

Those whose education was based upon the linguistic system almost exclusively, as was the case both before and after Priestley's time, could not be expected to realize the magnitude and true bearing of the power of science, and its educational value. Now, however, the case is altered; and it is a subject for congratulation to reflecting men, that the introduction of the scientific element into the ordinary course adopted at our public schools is at length attracting serious attention, and that its importance has been insisted on in both Houses of the Legislature. The practical instinct of the nation is becoming alive to the necessity of making certain portions of the training of our youth consist in the systematic study of the elementary parts of properly selected branches of science; and it behoves all who are themselves engaged in the pursuit of science to consider in what way they can themselves aid in forwarding this object.

I need not here advert to the exploded notion, that the acquisition of the truths of science can in anywise endanger those of revelation; for truth is ever consistent. But it may not be superfluous to reassure the minds of some who imagine that science, like a fresh invasion of Vandals, will extinguish scholarship and classical learning. Language must indeed ever form the basis of our system of education; for it is the key that unlocks the stores of knowledge; and no languages are so fitting to form the groundwork as the tongues of ancient Greece and Rome, irrespective of the treasures of philosophy, eloquence, poetry, and history which they contain. They have that intellectual finish and completeness which belongs only partially to science. A moderate amount of classical knowledge can be, as indeed it ought to be, attained by every so-called educated mind, while for him

who would carry the critical faculty to a high state of cultivation, the study of the classics affords the means. These tongues constitute the basis of many of the modern European languages; and an acquaintance with their literature imparts a cultivation and a polish that it is almost vain to seek from any other source. Just as some minds seek to attain distinction in the wide domain of philology, other minds, as vigorous, though differently constituted, delight in the study of natural laws and affinities. It would be a hard thing to say that provision should not be made in our schools for the latter, as wide and liberal as it has been for the former.

It is not to be supposed that, because science is to form a part of the education of every gentleman, therefore it will constitute the pursuit of his mature years. What is needed is that he possess sufficient knowledge of its principles to qualify him to appreciate the advances which science is making, and to enable him to contribute intelligently towards its progress.

It is certain that if science is to form a useful portion of the education of a boy, it must be undertaken with the determination to deal with it as a matter of study: the same pains must be taken to ascertain that each boy understands the principle, for example, of the air-pump, or the meaning of the thermometric scale, as that he comprehends a rule in syntax or the analysis of a sentence. To do this, however, the instruction given must not be limited to a dry lecture on the principles of some branch of science once a week. These principles must be logically unfolded, and illustrated, when necessary, by experiments, and the structure of machines and apparatus explained by suitable diagrams; the boys must be taught to take notes of each lecture; and the ground covered must be made secure by following up the lectures with frequent examinations, both oral and written. These are as necessary to the successful study of a science as the writing of exercises, or the practice of construing, is to the accurate study of a language. Science is not merely to supply her facts; she is to be employed to develop the powers of the mind, and to discipline them for action. Hence it is of far more importance to instil principles, and to cultivate precision in observation, in thought, and in description, than it is to load the memory with mere facts, however valuable. In short, the system of *cramping* is to be eschewed, whilst the formation of habits of comparing, reasoning, and judging is to be encouraged in every way.

It may at first be difficult to meet with well-trained and competent teachers; but when once the want of instruction in science is proclaimed, the teachers will soon be forthcoming. Some years will, no doubt, elapse ere science is admitted to take equal rank, as a means of education, with the study of classical literature. Still it is but a question of time; and we cannot but hope that our Universities, following up the commencement which the youngest but not the least active amongst them, the University of London, has made in the establishment of Degrees in Science—we cannot but hope, I say, that the heads of our Universities will ere long feel it to be their duty, as unquestionably it will be their wisdom, to place themselves at the head of this new movement, which is destined to exercise so wide an influence upon the education of our people.

But it is time that we proceed to take a rapid survey of some of the principal points in the progress of chemistry during the last twelve months. The course of chemical discovery since our Meeting last year, though not marked by any very striking novelty, has nevertheless been steadily advancing. Ideas previously thrown out have been discussed and developed; and many of them are leading to new discoveries, or are being applied to explain phenomena before wrapped in obscurity.

Amongst the problems which have, for some time past, been engaging the minds of philosophical chemists, few are of greater interest than those connected with the idea of the atomicity of the elements. It is well known that chemists now distinguish between the *atomic weight* and the *equivalent* of an element; also that, owing to the labours of many distinguished men, amongst whom the names of Williamson, Kekulé, Odling, Cannizzaro, and Wurtz are the most prominent, a classification of the elements into families has been made; and that this classification rests upon what is known as the *atomicity* of the elements. One group of the elements, like potassium and chlorine, is regarded as *monatomic*, or usually equivalent in functions to one atom of hydrogen; a second, like oxygen and sulphur, is *diatomic*,

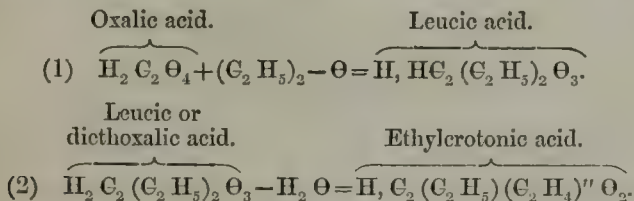
or equivalent in functions to two atoms of hydrogen; a third group, like nitrogen, phosphorus, and arsenic, is *triatomic*, or equivalent for the most part to three atoms of hydrogen; while a fourth group, like carbon and silicon, is *tetratomic*, or equivalent in functions to four atoms of hydrogen, and so on.

It would lead us too much into detail were I to attempt to show how this idea of the atomicity of the elements has been applied, and is still in process of application, to the study of the formation of compounds in general, how it endeavours to explain the existence of a limit to their number, and how it even teaches us to anticipate their possible varieties.

Among the subjects connected with its development is its bearing upon *isomerism*, or the remarkable fact of the existence in many cases of two or more bodies of different properties but yet composed of the same elements combined in identically the same proportions. Upon this subject, which, at our last Meeting, was characterized by Dr. Odling as the chemical problem of the day, a suggestive theoretical paper was published, about twelve months ago, by Dr. Crum Brown; whilst, in the same direction, Cahours, Kekulé, Beilstein, Fittig, and several other chemists have published valuable experimental researches. Inquiries of this kind are now acquiring special importance from the numerous cases of the formation of such isomeric bodies by the methods of synthesis and substitution, which are daily multiplying.

Closely connected with the same subject are the investigations into the constitution of the more complex organic acids, which have been prosecuted so actively during the last five or six years, and which, in the hands of Kolbe, Frankland, Perkin and Duppa, Kekulé, Wurtz, and their pupils, have made such rapid progress.

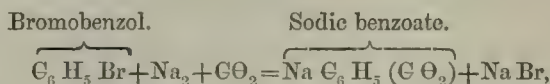
During the past year Frankland and Duppa have especially signalized themselves by their researches upon the lactic and the acrylic series. Two years ago, Frankland, commencing with oxalic ether, and acting upon it with zinc ethyl, obtained from it leucic ether by substituting ethyl for a portion of the oxygen contained in the oxalic ether; and afterwards, conjointly with his friend Duppa, he has generalized this reaction. Still more recently, these chemists have traced the connexion between the lactic and the acrylic or oleic series, by reactions in which the abstraction of the elements of an atom of water from the basylous portion of a member of the lactic group converts it into the corresponding member of the acrylic series. These relations will be readily understood by representing the different compounds by symbols, as follows:—



In these and kindred investigations, the necessity for the introduction of fixed principles of nomenclature for regulating the construction of names for the recently discovered compounds has been sensibly felt; and indeed the changes in notation rendered necessary by the alteration in the values assigned to the atomic weights of many of the chemical elements have rendered a general revision of the system of chemical nomenclature a matter of pressing importance. Probably few subjects could more usefully occupy a portion of the time of this Section during the ensuing week than a thoughtful consideration of the changes which it may be expedient to introduce. The meeting of chemists from various parts of Europe with many from distant parts of our own country affords an excellent opportunity for discussing a subject of this kind, where any conclusions, to be practically effective, must secure the concurrence of a majority of the active cultivators of the science.

Did time permit, it would be easy to mention other investigations in the organic department of chemistry, scarcely less interesting than those already alluded to, such as those on the synthesis of the aromatic acids by Kekulé, who has prepared both benzoic and toluic acid by the graduated action of sodium on an

etheral solution of bromo-benzol, and of bromo-toluol whilst submitted to a current of carbonic anhydride, as, for instance, may be explained by the equation—



or such as those of Maxwell Simpson and of Baeyer on the artificial formation of tribasic acids; and, referring to methods of research, stress might be laid on the important aid afforded by the extended use of the amalgam of sodium as a reducing agent, and on the similar but still more remarkable reducing-effects of hydriodic acid,—processes, indeed, not new, but the value of which till quite recently has only been partially recognized.

Passing allusion only can now be made to some of the processes of mineral and metallurgic chemistry, such as the improvements in the details of the process for preparing magnesium, the comparative facility with which the recently discovered metals thallium, rubidium, and cesium and their compounds may be obtained, and the application by Redtenbacher of his observation of the sparing solubility of their alums to the extraction of the new alkalies from the lithium residues of commerce. Of indium, too, the latest of the newly discovered metals revealed by the spectrum, it must suffice to say that it has been obtained in quantity which places its existence as a distinct metal beyond question. I am indebted to my friend Professor Roscoe for the small specimens of the metal and its sulphide now upon the table.

An extensive branch of industry is now springing up in the improved methods of voltaic deposition of the metals. Weil has, by the use of an alkaline solution of tartrate of copper, contrived to coat iron and steel with a tough closely adherent sheathing of copper, by simply suspending the articles to be coated by means of a wire of zinc in the metallic bath. No battery is required. Lead and tin may in a similar manner be deposited on copper, iron, or steel, if the oxide of tin or of lead be dissolved in a bath of strong solution of caustic soda.

I must, before I conclude, advert to one or two interesting additions to our knowledge upon the side where chemistry and physics meet. Few results, perhaps, were more unexpected than those obtained by Deville and Troost upon the permeability to gases of certain dense metals at elevated temperatures. They have proved that platinum and iron, when white-hot, become for the time porous, and are rapidly permeated by hydrogen, which will even pass out under the pressure of the atmosphere and leave a vacuum almost perfect within the tube. In one form of these experiments, tubes of hammered and of cast platinum (which in one case was as much as a twelfth of an inch in thickness) were fitted by means of corks into the axis of a shorter and wider tube of glazed porcelain; a slow current of pure and dry hydrogen was then maintained through the porcelain tube, whilst a current of dry air was transmitted through the platinum tube. At ordinary temperatures no change was observed in either gas. A fire was then lighted around the outside of the porcelain tube, and gradually raised until the heat became very intense. At 2000° Fahr. the oxygen contained in the air had entirely disappeared; nothing but nitrogen mixed with steam passed out of the platinum tube, hydrogen had passed through the pores of the platinum and entered into combination with the oxygen of the air within; whilst at still higher temperatures the moist nitrogen became mixed with hydrogen. As the tube cooled, the same phenomena occurred in the inverse order, till, when the ordinary temperature had been regained, no diffusion of hydrogen was perceptible, and unaltered air was collected from the platinum tube. Analogous results were obtained when a tube of soft cast steel was substituted for that of platinum, though the thickness of the steel tube was an eighth, or in some cases as much as a sixth of an inch.

From these experiments one practical conclusion deducible is, that air-pyrometers, the bulbs of which are formed of iron or platinum, cannot be relied on when employed for measuring elevated temperatures; glazed porcelain, however, was found to confine the gases completely.

Curious as these results are, they are but parenthetical in another series of more

general bearing, in which Deville has for some time been engaged, viz. the phenomena of *dissociation*, as he has termed the partial decomposition which compound gases experience under the influence of a temperature more or less elevated.

A very striking result was obtained by the use of an apparatus similar to that employed in the experiments just described, but in which a brass or silvered tube was substituted for the platinum or iron tube. A rapid flow of water was maintained through the metallic tube, so that it was kept quite cool, whilst the outer porcelain tube was gradually raised to an intense heat as before. On transmitting a current of pure and dry carbonic oxide through the porcelain tube, the lower part of the surface of the cold metallic tube became covered with deposited carbon, whilst a portion of the carbonic oxide, by combining with the oxygen previously united with this carbon, became converted into carbonic anhydride.

Sulphurous anhydride was by similar treatment resolved into sulphur and sulphuric anhydride; and even hydrochloric acid was partially separated into hydrogen and chlorine. These experiments are intimately connected with the attempts made to explain the cause of certain exceptions to Ampère's law, that *equal volumes of gases or vapours contain the same number of molecules of each*. Chemists now generally assume that the molecule, both of simple and of compound bodies, forms two volumes of vapour, and consequently that the molecular weight of any substance corresponds with the number which represents twice its density when referred to the density of hydrogen, if this be taken as unity. But there are exceptions to this law: pentachloride of phosphorus, hydrochlorate of ammonia, hydriodate of phosphuretted hydrogen, and various other bodies, instead of forming two volumes when one molecule of each is converted into vapour, yield four volumes.

In order to explain these anomalies, Kopp and Cannizzaro suppose that, at the temperature at which the vapour-densities of these compounds are observed, the bodies are temporarily decomposed, and, instead of forming one homogeneous vapour, are at the time of the observation really composed of a mixture of vapours. In certain cases this explanation is probably the true one; but its general acceptance has been disputed by Deville himself, though his results on dissociation seem, to cursory observation, to be in its favour; and it must be admitted that, up to the present time, the arguments and experiments which he has brought forward in opposition to the views of Kopp and Cannizzaro have not been satisfactorily answered.

No sufficient proof, for example, has yet been adduced that the well-known anomalous cases of nitric oxide, chlorous anhydride, hydrosulphide of ammonium, cyanide of ammonium, and various other salts of ammonium and the volatile bases are due to dissociation of their components.

This subject is one, however, too intimately connected with the molecular theories at present under discussion to remain long in its actual state. New experiments and evidence will no doubt be forthcoming, which will throw further light upon the cause of these outstanding exceptions.

Notes on Compounds of Copper and Phosphorus. By F. A. ABEL, F.R.S.

Mr. Abel gave an account of experiments instituted by him a few years ago upon the several combinations of phosphorus with copper, and upon the properties of copper containing small proportions (from 0.3 to 4 per cent.) of phosphorus, with special reference to their application to military and other purposes, as substitutes for the copper and tin alloy known as gun-metal.

Mr. Abel's experiments confirmed H. Rose's statements with regard to the formation of the phosphides having the composition Cu_6P and Cu_3P , but showed that the diphosphide of copper (Cu_2P) could not be produced by the action of hydrogen at a high temperature upon the diphosphate, as stated by Rose. The product richest in phosphorus, obtained by this method, approached in composition to the hexaphosphide, but, generally, the proportion of phosphorus found in the products, after separation of the phosphoric acid produced, was between 3 and 8 per cent. The diphosphide of copper heated to redness, out of contact with air, or in a current of hydrogen, was moreover found to be reduced to the hexaphosphide.

In experiments upon the direct union of phosphorus with copper, the maximum proportion of that element with which the metal would combine was found to be about 12 per cent. In operating upon a large scale, the products were rarely so rich in phosphorus; those most readily prepared contained from 3 to 5 per cent. of that element.

Phosphorized copper, containing not more than 0·5 per cent. of phosphorus, is more fusible and flows much more readily than copper. When cast in iron moulds, it contracts very considerably, and has, when cold, a very compact and uniform structure. If cast in moulds of sand or loam, the phosphorized metal is always open in structure. The shrinkage of the metal, when cast in chills, renders the production of any but very simple castings difficult to accomplish; but when sound castings are obtained, they exhibit great superiority over gun-metal castings in point of tenacity. The average "breaking weight" of gun-metal being about 32,000 lbs. on the square inch, that of phosphorized copper, containing 0·5 per cent. of phosphorus, was found to be 38,389 lbs.; while the strain borne, up to fracture, by metal containing 0·75 per cent., amounted to 45,500 lbs. The phosphorized metal containing from 0·3 to 0·5 per cent. of phosphorus could not be rolled or worked under the hammer when heated even below redness, and required careful working when cold.

Some results of experiments on the influence exerted by the presence of iron, in phosphorized copper, upon its composition and properties, were also described by Mr. Abel.

Observations on the Utilization of Sewage, as conducted at Stroud, and on the Growth of the Sewage Plant. By H. BIRD.

On the Preservation of the Sheathing of Ships, and Extraction of Silver from Sea-Water by means of Electricity. By J. C. BOWRING.

On the Direction of the Electric Current. By J. C. BOWRING.

Action of Acids on Metals and Alloys. By Dr. CRACE-CALVERT, F.R.S.

The author, in the name of Richard Johnson, F.C.S., and himself, communicated to the members of the Section some of the leading facts that they had observed in studying the action of acids on metals and alloys. As it was impossible to attempt to go into details in the short space of time allowed him to bring the subject before the Meeting (for their researches extended over twelve months, and contained two or three hundred experiments), he would confine his observations to the action of sulphuric acid upon zinc.

The first fact that he would bring before the notice of chemists was that, contrary to the generally received opinion, sulphuric acid at the natural temperature did not act upon pure zinc if the surface of the metal submitted to the action of the acid was perfectly free from any trace of oxide, whilst if there was the slightest oxidation, a slight action commenced, gradually increasing until in some instances it assumed the appearance of ordinary zinc when acted upon by sulphuric acid, viz., a violent action.

Another curious and interesting fact is, that mono- and bi-hydrated sulphuric acids, besides having no action, as stated, at the natural temperature, exercise but a limited action also at a temperature of 130° C. and 150° C.; for in the space of two hours sulphuric acid dissolved on 1 metre surface, with the mono-hydrated acid, respectively 125 and 386 grammes, and with the bi-hydrated acid 236 and 575 grammes; whilst if, on the contrary, sulphuric acid with 3 equivalents of water was employed, the increased action was really remarkable, being more than twenty times as great, for the respective quantities dissolved on a metre surface were 8193 and 9083 grammes; and even with sulphuric acid containing 4, 5, and 6 equivalents of water, the actions decreased materially; in fact the action of $\text{SO}_3 + 6\text{H}_2\text{O}$ was identical with that of $\text{SO}_3 + 2\text{H}_2\text{O}$, whilst the violent action was resumed with sulphuric acid containing 7 equivs. water, for at a temperature of 100° C. (the boiling-

point of the acid) as much as 5260 grammes were dissolved, to fall again to a low figure with $\text{SO}_3 + 8 \text{HO}$.

He did not doubt that these results would prove of great value to electricians in drawing their attention to the necessity of studying with care the strength of the acid employed in their batteries.

The action of heated concentrated sulphuric acid on zinc appears to divide itself into two distinct phases, in one of which sulphuric acid is decomposed, and sulphurous acid given off; and the other in which water is decomposed and sulphuretted hydrogen given off.

With mono-hydrated sulphuric acid only sulphurous acid is given off; with bi-hydrated sulphuric acid, a large quantity of sulphurous acid is evolved, and only a trace of sulphuretted hydrogen; whilst with sulphuric acid containing 3 equivs. of water, large quantities of sulphuretted hydrogen are produced, and only traces of sulphurous acid.

Dr. Crace-Calvert and Richard Johnson have also studied the action of sulphuric acid on copper and tin, and on brasses and bronzes; also the action of hydrochloric and nitric acids on the same metals and their alloys; the interesting facts they have observed will be found in a paper which they intend to publish shortly.

On the Reactions of Cyanogen. Note on Glycorine, with Tables.

By T. FAIRLEY.

On the Utilization of Blast-Furnace Slag. By FREDERICK GEORGE FINCH, B.A., D.Sc. (Lond.), F.G.S., Assoc. Roy. School of Mines.

In this paper the author, after referring to the various attempts that have been made both in this country and abroad to utilize the slag from iron-smelting furnaces, described a method now adopted to effect this object at several ironworks in France and Belgium. The slag is there allowed to run direct from the furnace into pits about 8 or 9 feet in diameter at the top, with sides sloping inwards towards the centre, where they are about 3 feet deep. The mass is left for eight or nine days to cool, when a hard, compact crystalline stone is obtained, which is quarried and used for building purposes, but chiefly for paving-stones. It is on this last application that its commercial value seems principally to depend. These paving stones are laid down in several provincial towns in France and Belgium, and also in some parts of Paris. They appear to wear exceedingly well, and are certainly superior to the grits and sandstones generally used for that purpose in those countries.

This manufacture, besides being the means of getting rid of what has hitherto been a useless and cumbersome material, is found at the above works to answer in a pecuniary point of view. The large area required for the pits would prevent its adoption at many ironworks in this country.

On some Minerals from South America. By DAVID FORBES, F.R.S., &c.

The following minerals were exhibited, and the results of their chemical examination reported:—

Taltalite, a black mineral from the desert of Atacama, much resembling shorl, and which proved to be a silicate of copper and alumina with part of the alumina replaced by sesquioxide of iron, Domeykite, algadonite, and Darwinite, all from Chili, being three distinct basic arsenides of copper, represented respectively by the formulæ $\text{Cu}_6 \text{As}$, $\text{Cu}_{12} \text{As}$, and $\text{Cu}_{18} \text{As}$. The mineral Darwinite was proved identical with a mineral which had been about same time found at Lake Superior, and which had been called Whitneyite. Telluriferous native bismuth, bismuth glance, and Danaite from Sorata in Bolivia; a new selenide of silver and nickel from near Mendoza. Iodides, chlorobromides, and chlorides of silver, all crystallized from near Copiapo in Chili, and an amorphous yellow mineral from the interior of the desert of Atacama in Chili, which was an oxyiodochloride of lead. Three differently crystallized varieties of oxychloride of copper or Atacamite was shown from the coast of Bolivia and Chile, along with several other rare or finely crystallized minerals.

Attention was directed to hexagonal crystals of metallic copper from the mines of Corocoro in Bolivia, out of the red sandstones there; these were regarded by the author as pseudomorphs, after Arragonite, as although some of them were found to consist of solid metallic copper, yet others on being sawn across were found to contain a greater or less nucleus of white carbonate of lime. The formation of these pseudomorphs was explained as having resulted from the action of a solution of protosulphates of copper and iron produced by the oxidation of ordinary copper pyrites on crystals of Arragonite or carbonate of lime.

Synthetical experiments were related confirmatory of this view, as some crystals of Iceland spar, on being kept some months in a stoppered bottle along with a mixed solution of sulphate of copper and protosulphate of iron, were soon converted superficially into carbonate of copper, which in turn was reduced to metallic copper by the deoxidating action of the protosulphate of iron.

On the Colour of Gold as seen by transmitted Light.

By DAVID FORBES, F.R.S., &c.

The author found in several instances where solutions of gold had been precipitated by oxalic acid, that an extremely thin film of gold adhered very pertinaciously to the side of the glass vessel, and that this film, when looked at by transmitted light, was quite blue, and did not at all present the green colour attributed to gold in a fine state of division, as in the common experiments of holding up a thin gold-leaf between the eye and the light.

He concluded from this that the true colour of gold by transmitted light was blue, and that the green colour usually observed was due to this blue colour being mixed with yellow light reflected from the polished surface of the hammered gold-leaf.

A most conclusive experiment corroborated this view. In order to get a film of gold infinitely finer than the thinnest gold-leaf, the author took a quantity of the so-called ruby glass of commerce, the colour of which is due to a minute quantity of gold which enters into its composition (amounting to a six-hundredth of a percentage only), and reduced the gold in this to its metallic state by heating it in an atmosphere of carbonic oxide. The film of gold thus produced, when examined by transmitted light, afforded a most beautiful and pure blue colour without any trace of green whatever.

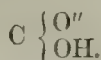
On the Constitution of the Acids of the Acetic, Lactic, and Acrylic Series. By Dr. FRANKLAND, F.R.S., Professor of Chemistry in the Royal Institution of Great Britain, and in the Royal School of Mines.

In conjunction with Mr. Duppa, the author had for some time past been engaged in investigating synthetically the constitution of the acids belonging to the acetic, lactic, and acrylic series. They had succeeded in building up the higher members of the acetic series from acetic acid itself, by the substitution of hydrogen in that acid atom for atom, by the alcoholic radicals, methyl, ethyl, &c. Numerous new members of the lactic series had been in like manner constructed from oxalic acid, by the substitution of one atom of oxygen ($O=16$) by two atoms of the alcohol radicals, whilst several members of the acrylic series had been produced from the lactic series by the abstraction of an atom of water from the latter.

These investigations had led to the following conclusions:—

1. The acids of all three series are constructed upon the radical type. They are all double radicals, composed of a chlorous and a basylous constituent.

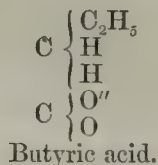
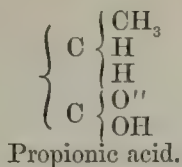
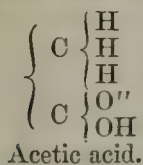
2. The chlorous constituent is the same in all, and consists of an atom of methyl, in which two atoms of hydrogen are replaced by one of oxygen, and the remaining atom of hydrogen by hydroxyl,



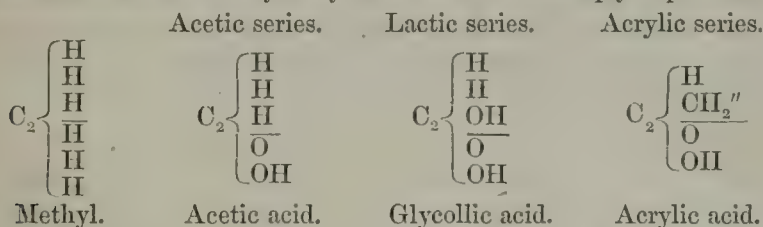
It is this chlorous constituent which determines the basicity of these acids, and its repetition twice or thrice in a molecule produces dibasic or tribasic acids.

3. The basylous constituent is variable, both homologously and heterologously.

Its homologous variation produces the different members of each series; thus in the acetic series we have—



Its heterologous variation, on the other hand, gives rise to the different series of acids, of which the acetic, lactic, and acrylic series are examples. In the acetic series the basylous constituent is always either methyl or an alcohol radical, derived from methyl (except in formic acid, where it is hydrogen). In the lactic series it is an alcohol radical, derived from methyl, in which one of the typical atoms of hydrogen is replaced by hydroxyl (OH); whilst in the acrylic series it is a similar alcohol radical, in which two of the typical atoms of hydrogen are replaced by a diatomic member of the olefiant gas family. The relations of these three series of acids to each other and to methyl may therefore be thus simply expressed:—



On the Sanitary and Economical Aspects of the Sewage Question.
By Dr. HILL (Borough Analyst, Birmingham.)

The author stated that his attention had been drawn to this subject by examinations he had made of the well- and river-water of Birmingham, and the immediate neighbourhood. After many examinations, he considered that the water in question was generally contaminated with foreign matter, frequently organic matter, and resulted, as he believed, from the present system of sewage removal. Samples of water of the town yielded various quantities of solid matter, varying, in fact, from 12 grains per gallon to 30, 40, or even in one instance, to 260 grains per gallon. The principal constituents of the solid matter were salts of lime, magnesia, and soda, together with organic matter. He had not used the permanganate test for organic matter, but adopted the usual process of incineration, and found that his results showed in some instances the presence of 65 grains of organic matter and volatile salts per gallon. In the course of the process large quantities of nitrous fumes were evolved. With respect to rivers, he had examined the waters of two rivers near where they united. Sewage matter entered one of them near their junction; and he was enabled to ascertain the effect of sewage matter upon the water. Before the entrance of the sewage, he found 1.3 grain per gallon of organic matter, and after admixture he found 12 grs. of organic matter. The author argued that the present water-closet system was entirely wrong, and that we ought to resort to the old method of cesspools, and then have the solid matters removed direct to the land.

On the Results of Agricultural Experiments made in 1864.
By Dr. STEVENSON MACADAM, F.R.S.E., F.C.S.

The experiments referred to were undertaken at the author's suggestion by agriculturists in Roxburghshire, and form one of the first series of field experiments carried on in a systematic manner in Scotland. Twelve different manurial mixtures were used in the trials, and formed a set of experiments, whilst ten farmers made arrangements for carrying out the experiments in the field. The manurial mixtures employed consisted of Peruvian guano, phosphatic guano, phospho-guano, bone-ash,

superphosphate, guano-superphosphate, sulphate of ammonia, and ground bones, taken singly or mingled together in definite proportions. The manures were analyzed so as to be certain of their exact composition. In each set of experiments the various operations were conducted on the same day with the plots of ground allotted to each manure. The soils on which the experiments were made were in part of a heavy nature, and in other parts of a light character—the proportion of each being equal. Each experiment was conducted on a quarter of an acre, and the twelve experiments consequently required three acres on each farm. The crop was turnips, and the yield or produce was weighed on the field. The results obtained were various on the different farms, as the manures which gave the largest returns on one farm did not yield the largest crop on another. These variations are to be expected in all field experiments, and are due to the special circumstances or conditions of each field where the trials are made. Where only one set of experiments are conducted on a single farm, the local influences may materially affect the results; but where, as in the present case, the field operations are conducted on ten farms, and the mean produce of the ten trials is obtained, then the disturbing influences of one farm are counteracted or practically neutralized by those of the other farms.

The full extent of the differences in the yield of the various manurial mixtures may be more readily comprehended from the following Table, which gives the manures in the order of their fertilizing powers according to the mean of all the experiments:—

| Manure for Quarter of an Imperial Acre. | | Average produce per Imp. Acre. | | | |
|---|--|---|------|-----|-----|
| | | Calculated from the mean money value (8s. 5d.) of each lot or manurial mixture. | | | |
| | | In Bulbs. | | | |
| | | Tons. | cwt. | gr. | lb. |
| (1) I. | 9 Stones 35 p. c. Guano Superphosphate | 21 | 12 | 2 | 19 |
| (2) J. | 5 Stones Peruvian Guano | 21 | 12 | 2 | 0 |
| (3) II. | 9 Stones 35 p. c. Bone-ash Superphosphate | 20 | 14 | 1 | 8 |
| (4) C. | { 8 Stones 35 p. c. Bone-ash Superphosphate }
{ 1 Stone Peruvian Guano | 20 | 1 | 3 | 0 |
| (5) G. | { 4 Stones 35 p. c. Bone-ash Superphosphate }
{ 5 Stones Ground Bones | 20 | 0 | 0 | 18 |
| (6) F. | { 8 Stones Phosphatic Guano..... }
{ 1 Stone Sulphate of Ammonia | 19 | 2 | 0 | 26 |
| (7) E. | { 6 Stones 35 p. c. Bone-ash Superphosphate }
{ 2 Stones Bolivian Guano | 18 | 8 | 3 | 16 |
| (8) D. | { 1 Stone Sulphate of Ammonia..... }
{ 8 Stones 35 p. c. Bone-ash Superphosphate } | 18 | 8 | 2 | 23 |
| (9) B. | { 1 Stone Sulphate of Ammonia | 18 | 7 | 2 | 6 |
| (10) K. | { 7 Stones 35 p. c. Bone-ash Superphosphate }
{ 2 Stones Peruvian Guano..... } | 18 | 2 | 2 | 12 |
| (11) A. | { 9 Stones Phosphatic Guano..... }
{ 6 Stones 35 p. c. Bone-ash Superphosphate } | 17 | 12 | 1 | 18 |
| (12) L. | { 3 Stones Peruvian Guano | 17 | 4 | 0 | 19 |
| | { 6 Stones Phospho-Guano..... } | | | | |

It will thus be observed that, taking the mean produce from the ten trials, calculated to the same money value for each of the manures, the greatest return of crop was yielded by the dissolved phosphatic guano, followed closely by the Peruvian guano. Indeed the difference in the produce obtained from the plots treated with these manures was so slight—only 19 lbs. to the acre—that they may be re-

garded as having yielded the same results. In referring to these experiments, it must be remembered that the season of 1864 was exceptionally dry, though the drought was not so great in Scotland as it was in England. The results obtained, however, are valuable as representing the produce obtainable in a dry season; and as a similar series of field experiments are being made this year in the same district, an opportunity will be obtained for contrasting the results for both years.

On Esparto Fibre, or Spanish Grass, and its Employment in the Manufacture of Paper. By Dr. STEVENSON MACADAM, F.R.S.E., F.C.S.

During the last three years large quantities of a grass obtained from Spain have been employed in this country in the manufacture of paper. Delivered in Great Britain, it costs about £5 10s. to £6 per ton. The recent high price of rags has caused a demand for esparto fibre; and should it continue, other countries, as Barbary, which yield the same grass will no doubt contribute largely to the supply. The chemical composition of an average sample is—moisture, 9.62; oil, 1.23 albuminous compounds, 5.46; ligneous fibre, 56.28; starch, gum, and sugar, 22.37; ash, 5.04. In the manufacture into paper, the material, first carefully cleaned, is subjected to the action of caustic soda. The fibre, however, is rather short in nature, and hence paper entirely made of it is extremely liable to tear. It is customary, therefore, to give strength by mixing the pulp from esparto fibre with the pulp from rags, commonly in the proportion of equal parts. The paper so manufactured is largely employed as a printing paper, and the majority of the Scotch newspapers are now printed on it. The spent soda liquor, being of a caustic nature, is highly pernicious and destructive to fish, when it is run directly into a fish-stream; even if diluted to the extent of many times its own volume, the liquid possesses the power of killing them within a few hours. Two plans have been suggested and put in operation for the arrestment, more or less completely, of the soda liquor. The first, the boiling down the ley, heating the residue with carbonaceous matter, such as fine coal or sawdust, and the recovery of the soda from the calcined mass; the second, the reception of the liquor in large open cesspools, where it may percolate through the soil. Both plans have been successful.

On Crystals of Melanconite, and on Tenorite. By Professor MASKELYNE, M.A.

Professor Maskelyne described crystals of oxide of copper (melanconite) that had recently been found by Mr. Talling of Lostwithiel. They are brilliant in lustre and of a dark steel-grey colour, and occur in a chloritic vein-stone. Their crystallography presents considerable difficulty from the corrugated and uneven character of certain of the faces, and the incompleteness of the crystals. But measurements made on three or four selected crystals establish the oblique system as that of the mineral.

The planes met with are (100)*a*, (001)*c*, (011) (111) ($\bar{1}11$) (001) (611), and the crystallographic constants of the mineral are given by the values of the parameters,

$$a : b : c = 1.4902 : 1 : 1.3604,$$

and of the inclination of normals to *c*, *a*, viz. 001, 100 = 80° 28'.

The fracture is generally conchoidal, and cleavages exist parallel to (111) and (001), the latter a facile one. The crystals are generally twinned; one twin plane is 100.

The hardness is a little above 4, the specific gravity = 5.82527.

The mineral Tenorite, the form of cupric oxide, found in certain old lavas of Vesuvius consists in fine ribbon-like fibres, transparent under the microscope, and presenting feather-like twinned aggregates of laminated crystals. The individual crystals cleave readily with an angle of a little more than 72°.

They present the interesting property of absorbing one of the polarized rays of a beam of light traversing them, just as does a plate of tourmaline cut parallel to its optic axis. It is not impossible that Tenorite may represent the melanconite crystal in laminæ parallel to 100.

The sooty blackness of cupric oxide in its powdered and more massive form may

be due to the extinction of light by the absorbing action of the crystal on one of the polarized beams.

A few words on Sponges as a Source of Bromine and of Nitrogen.

By Dr. PHIPSON.

On the Sublimed Oligist of Vesuvius, and its Artificial Production.

By Dr. PHIPSON.

On Silicium in Iron. By Dr. PHIPSON.

On the Action of Light upon Sulphide of Lead, and its bearing upon the Preservation of Paintings in Picture Galleries. By Dr. D. S. PRICE, F.C.S.

The author's attention was directed to this subject by observing that in the cases in the Technological Museum under his charge at the Crystal Palace, which are painted with white-lead, substances which emitted sulphurous vapours did not cause a darkening of the surface of the case, excepting where it was protected from the direct influence of light. A number of experiments was then tried as to the action of light upon sulphide of lead produced by the action of sulphuretted hydrogen on lead paint. A board painted white with white-lead was exposed for several hours to the action of sulphuretted hydrogen, until the surface had acquired a uniform brown colour. Plates of glass of different colours were then placed upon the painted surface, one portion being at the same time covered with an opaque medium, and another left entirely exposed. The board was then placed facing the light. The glasses employed were red, blue, yellow (silver), violet, and smoke-colour glass. The results exhibited were after an exposure of eight days, and showed that the parts of the board directly exposed to light were bleached; those protected by an opaque medium were not acted upon, while with the glasses of different colours intermediate effects were produced, those of the blue glass being most decided. Drying-oils in conjunction with light rapidly bleach sulphide of lead, and boiled oil effects the bleaching still more rapidly. When water-colour is used bleaching takes place, but much more slowly than in the case of oil. After quoting authorities, stating that generally light was advantageous to the preservation of pictures, Dr. Price showed a striking illustration of this fact. He had a picture painted, and then exposed it to the action of sulphuretted hydrogen, until it became sadly discoloured, and to all appearance destroyed. Some strips of paper were laid across the picture so as to cover some parts. The picture, thus partially covered, was exposed to light for a long time. The result, as shown at the Meeting, was curious indeed—the parts of the picture exposed being perfectly restored, while those protected by the paper remained still discoloured. From his experiments he came to the conclusion that it was advantageous to have picture-galleries well lighted, especially where, as in towns, the atmosphere was charged with sulphur compounds, and that it was quite a mistake to have curtains placed in front of pictures with a view to their protection. In the course of his communication, Dr. Price stated that it was curious to observe in many parts of London the discoloration of houses painted with white lead. He had frequently seen the lower portions completely coated with a metallic-like surface of the sulphide, and had little doubt that the formation of this compound would be found to be more frequent in winter than in summer, and more prevalent on the shady than on the sunny side of a street.

The Progress of the Manufacture of Gun-Cotton, and its application to Mining, Military, and Sporting Purposes. By MANNING PRENTICE.

On the Properties of Parkesine, and its Application to the Arts, Manufactures, and Telegraphy. By OWEN ROWLAND.

Parkesine is so called after its inventor, Mr. Alexander Parkes, of Birmingham, the well-known discoverer of the cold process of vulcanization of Indian rubber. This material is suitable for a great variety of purposes, possessing properties kin-

dred to india-rubber and gutta percha; it can be produced of any colour or shape, and can be manipulated in almost every conceivable manner. The basis of the material Parkesine is gun-cotton, but a variety of other materials are used. These materials were exhibited: they consisted of various solvents, cotton waste, oils, &c. Various articles, manufactured from Parkesine, were shown, and its various applications thus proved. A cotton which is not readily explosive, is desirable in the manufacture; iodide and chloride of zinc being used to prevent the rapid combustion of the cotton. Mr. Parkes's solvent is suitable for the solution of india-rubber, gutta percha, and various gums; and by mixing these substances in various proportions, the different varieties of Parkesine are made. The author then referred to the value of Parkesine as an insulating material for telegraphic purposes, considering it far superior to india-rubber and gutta-percha, or to any combination of materials hitherto used. The strength of the material is considerable, a cable of it being capable of supporting one mile in length of its own substance, whilst sound joints can be made with the greatest facility.

On the Action of the Alkali Metals in determining the Explosion of Gun-Cotton.

By WENTWORTH L. SCOTT, F.C.S., F.A.S.L., &c.

The author stated that in the course of some experiments he accidentally dropped a piece of potassium on some gun-cotton; the gun-cotton immediately exploded. He then instituted a series of experiments, to ascertain what conditions were essential for explosion to take place, whether the explosion was due to moisture, whether other metals would act similarly on the gun-cotton, &c. He found that by taking precautions to prevent friction, the gun-cotton still exploded. When sodium was used a like result was obtained, even though the gun-cotton was rendered perfectly anhydrous. If an amalgam of potassium or sodium was used no result was obtained. Various metals were tried, but decided effects were obtained only with the metals of the alkalis, although finely-divided metallic arsenic has the property of increasing the explosive powers of gun-cotton, the mixture readily exploding on percussion, and the author thought the same might be usefully applied.

On a Method of estimating Carbonic Acid in the Air.

By Dr. ANGUS SMITH, F.R.S.

The author explained a mode of analysis which he has called minimetric. The idea, he said, might perhaps not be quite new, but it is well to give the method a name. It is based mainly on the fact that we can retain in the memory with great exactness the character of a precipitate of a given degree of translucency. For carbonic acid, the author finds a precipitate of carbonate of baryta, formed in half an ounce of baryta-water by 0.2515 cub. centim. of carbonic acid, or by nearly three times that amount in lime-water, to be most easily remembered. If the carbonic acid in air is sought, the air is made to act on the baryta-water until the desired precipitate is obtained. In other words, we use the *smallest measure* of air which will produce the precipitate. For this reason the name *minimetric* is adopted. The method may also be used for hydrochloric acid, sulphuric and sulphurous acids, sulphuretted hydrogen, &c., and probably has been used frequently without being brought forward as a method for accurate use.

Two ways of using this method of analysis were described. The first was by the use of a finger pump, an elastic ball with two valves, connected with a bottle containing baryta-water. On pressing the ball the air in it is driven out, and on removing the pressure-air is drawn in through the liquid. The air and liquid are then shaken together, and the operation repeated until the precipitate is obtained. For ordinary use a ball to contain two ounces is found most suitable; the bottle should have the same capacity as the ball + the space required for the liquid, so that the air contained in the bottle at the commencement of the experiment may count as one ballfull.

A Table is constructed like the following, but of course it must be adapted to the size of the ball.

| Number of strokes of the finger pump, or number of ballfuls of air. | Per cent. of carbonic acid indicated in the air. | Actual amount of carbonic acid in one ballful of air. |
|---|--|---|
| | | cub. centims. |
| 1 | 0.444 | 0.2515 |
| 2 | 0.222 | 0.1257 |
| 3 | 0.148 | 0.0838 |
| 4 | 0.111 | 0.0629 |
| 5 | 0.088 | 0.0503 |
| 6 | 0.074 | 0.0419 |
| 7 | 0.063 | 0.0359 |
| 8 | 0.055 | 0.0314 |
| 9 | 0.049 | 0.0279 |
| 10 | 0.044 | 0.0251 |
| 11 | 0.040 | 0.0229 |
| 12 | 0.037 | 0.0209 |
| 13 | 0.034 | 0.0193 |
| 14 | 0.032 | 0.0180 |
| 15 | 0.030 | 0.0168 |

The number of ballfuls required to produce the precipitate being counted, on referring to the Table the percentage of carbonic acid in the air is at once seen. An easy method of finding the precipitate for comparison is by shaking half an ounce (14.17 cub. centims.) of baryta-water in a bottle with 23 ounces of Manchester air, or nearly 30 ounces of London air (and elsewhere according to residence.)

Experiments made with this apparatus show it to be extremely delicate. The carbonic acid in the air of a room can be estimated in a few minutes. For very bad air smaller balls are used, but in all cases only half an ounce of baryta-water.

The second way of using the minimetric method was partly described in the report on the air of mines, and long tables were there given both for baryta- and lime-water. It is more particularly adapted for use in houses and workshops.

Suppose we desire to know if the air contains more than 0.04 per cent. carbonic acid, we fill a bottle containing 5.422 ounces with air, by pumping or otherwise, and shake in it half an ounce of baryta-water. If there is any precipitate at all, the amount of carbonic acid in the air is above 0.04 per cent. This would indicate that the air is less pure than outside.

If we allow 0.06 per cent. of carbonic acid in a room, we take a bottle of the size of $3.281 + \frac{1}{2}$ ounce = 3.781 ounces (or 107.19 cub. centims.), and if after trial as above, we find a precipitate, however small, or even a slight milkiness, the air is deteriorated beyond 0.06. This relates to dwelling-houses.

If for workshops we allow $\frac{1}{4}$ per cent. (0.25), a bottle of $0.788 + \frac{1}{2}$ ounce = 1.288 ounces (or 36.51 cub. centims.) is sufficient.

If $\frac{1}{2}$ per cent. is allowed (0.50), a bottle of $0.394 + \frac{1}{2}$ ounce = 0.894 ounce (or 25.34 cub. centims.) is enough.

Both of these two last sizes of bottles are small enough to be carried in the waistcoat pocket. The addition of the $\frac{1}{2}$ ounce is for the space occupied by the baryta-water.

Lime-water, being very common, will probably be often substituted for baryta-water. The experiment is exactly the same, only larger bottles are required.

0.06 per cent. carbonic acid in the air gives no precipitate or milkiness when $\frac{1}{32}$ an ounce of lime-water is shaken in a bottle of air containing 10.567 ounces (= 299.57 cub. centims.).

0.25 per cent. carbonic acid in the air gives no precipitate or milkiness when $\frac{1}{32}$ an ounce of lime-water is shaken in a bottle of air, containing 2.916 ounces (= 82.67 cub. centims.).

0.50 per cent. carbonic acid in the air gives no precipitate or milkiness when $\frac{1}{32}$ an ounce of lime-water is shaken in a bottle of air containing 1.708 ounce (= 48.42 cub. centims.).

By this simple method the greatest refinement may be attained. Of course, care must be taken to have the baryta- or lime-water perfectly clear to begin with.

The author said he had not used these methods for purely scientific investigations.

On a Apparatus for the Determination of the Ozone in the Atmosphere, and Experiments made therewith by means of the Aspirator. By JOHN SMYTH, Jun., A.M., Mem. B.M.S.

The author being interested in linen bleaching, took daily meteorological observations for several years, in which he directed particular attention to ozone. He found the usual methods of testing its presence in the atmosphere unsatisfactory, and showed it is so by reference to a Diagram Chart of all the elements of the weather in 1864, prepared by him. He was therefore led to devise an apparatus, the principle of which is, by means of a large aspirator, to draw the air at a considerable velocity through a small tube, so as to impinge at its opening into a tube of larger diameter against an extended surface of test-paper. This ozonometer consists of two brass or opaque glass tubes or boxes about 2 inches long and 2 inches in external diameter, the smaller of which screws or fits tightly into the larger, and is about $\frac{1}{8}$ th of an inch shorter; its extremity at the point of the screw is grooved for an india-rubber band which holds the test-paper stretched across its mouth. The entrance-tube, $\frac{1}{4}$ th inch in diameter, is introduced into the centre of the solid extremity of the larger box, $\frac{1}{8}$ th of an inch from the centre of the test-paper. A small pipe from the solid extremity of the smaller box communicates with the aspirator, which the author prefers should be made on the plan of Dr. Andrews, of Queen's College, Belfast, viz., a gasometer of a capacity of about 80 gallons, connected by means of a cord to a clock in which an extra weight is slung, which raises the gasometer at a uniform velocity over which the pendulum gives complete control. A counterpoise is used to support the weight of the gasometer. The author showed, from a table of experiments made by this improved ozonometer, that there is not much difference in the quantity of sensible ozone in two masses of air of equal volume, moving at different velocities, in different directions, and under different hygrometrical conditions. Also that the test-papers in the ordinary ozone-cage do not register high enough; a more extended series of experiments may, however, somewhat modify these views.

On Phosphatic Deposits recently discovered in North Wales.

By Dr. AUG. VOELCKER.

An extensive mine, containing several phosphatic minerals, was accidentally discovered last year by Mr. Hope Jones, of Hooton, Cheshire, whilst he was searching for other minerals in the neighbourhood of Cwmgyngen, about sixteen miles from Oswestry.

The mine is continuous for more than nine miles, and occurs 12 feet under the surface.

It is not far from the clay-slate and lead-bearing district of Llangynog.

The strata (slaty shale) contain several beds of contemporaneous felspathic ash and scorïæ, and the usual fossils of the Llandeilo series are found, but not in great numbers.

The strata are vertical, and run east to west, or, more correctly speaking, 15 degrees north of west (magnetic).

A true vein or fissure containing vein deposit, partially metallic, divides two phosphatic deposits.

One of them is nearly 3 yards in thickness, and embodies phosphatic limestone beds, containing from 10 to upwards of 35 per cent. of phosphate of lime.

The other and more valuable deposit is a yard and a half thick, and consists of a black graphitic shale, largely impregnated with phosphate of lime.

This deposit is free from carbonate of lime, and much richer in phosphate of lime than the first-mentioned deposit.

In specimens taken at a depth of about 12 feet from the surface, Dr. Voelcker found from 54 to 56 per cent. of phosphate of lime in this phosphatic shale.

At a greater depth the shale becomes richer in phosphates, and consequently

more valuable; for in the deeper specimens the proportion of phosphate of lime amounted to $64\frac{1}{2}$ per cent.

This phosphatic mine is readily accessible and naturally drainable to a depth of about 500 feet, and contains many hundred thousand, if not millions of tons of valuable phosphatic minerals.

The following analyses may be given in illustration of the composition of the limestone and the black shale deposits.

A specimen of phosphatic limestone gave the following results:—

| | |
|----------------------------------|-------|
| Phosphoric acid..... | 16.12 |
| Lime | 30.42 |
| Oxide of iron..... | 2.34 |
| Alumina..... | 6.52 |
| Magnesia | 4.89 |
| Iron | 1.30 |
| Sulphur | 1.49 |
| Carbonic acid | 12.23 |
| Insoluble siliceous matter | 20.95 |
| Sulphuric acid | .16 |
| Organic matter and loss | 3.58 |

These constituents, united together in the usual manner, give the following composition for this phosphatic limestone:—

| | |
|--------------------------------------|-------|
| Tribasic phosphate of lime | 34.92 |
| Oxide of iron..... | 2.34 |
| Alumina | 6.52 |
| Carbonate of lime | 20.75 |
| Carbonate of magnesia..... | 5.92 |
| Magnesia in a state of silicate..... | 2.07 |
| Iron pyrites | 2.79 |
| Sulphuric acid | .16 |
| Insoluble siliceous matter | 20.95 |
| Organic matter and loss | 3.58 |

100.00

A specimen of black phosphatic shale, found at a depth of about 20 feet below the surface, furnished the following results:—

| | | |
|---|-------|--|
| Organic matter and loss | 3.98 | } Soluble in dilute hydrochloric acid. |
| Lime | 37.16 | |
| Phosphoric acid* | 29.67 | |
| Magnesia | .14 | |
| Oxide of iron..... | 1.07 | |
| Alumina..... | 5.84 | |
| Matters insoluble in dilute hydrochloric acid | 22.14 | |

100.00

A specimen of black phosphatic shale, taken at a depth of about 12 feet, on analysis yielded the following results:—

| | |
|----------------------------------|-------|
| Phosphoric acid..... | 24.07 |
| Lime | 32.31 |
| Oxide of iron | 2.01 |
| Alumina..... | 7.71 |
| Magnesia | .32 |
| Sulphuric acid | .26 |
| Iron | 3.51 |
| Sulphur | 4.01 |
| Insoluble siliceous matter | 22.44 |
| Organic matter and loss | 3.36 |

100.00

* Equal to tribasic phosphate of lime..... 64.16

Accordingly the composition of this specimen of black shale may be represented as follows:—

| | |
|---|--------|
| Tribasic phosphate of lime | 52·15 |
| Lime present as fluoride of calcium and as silicate | 4·23 |
| Magnesia | ·32 |
| Alumina | 7·71 |
| Oxide of iron | 2·01 |
| Sulphuric acid | ·26 |
| Iron pyrites | 7·52 |
| Insoluble siliceous matter | 22·44 |
| Organic matter and loss | 3·36 |
| | <hr/> |
| | 100·00 |

On the Composition of a Marine-Boiler Incrustation.

By Dr. AUG. VOELCKER.

A marine-boiler incrustation, analyzed by Dr. Voelcker, yielded the following results:—

| | |
|---|---------|
| Moisture | 1·01 |
| Water of combination | 7·48 |
| Oxides of iron and alumina, with traces of phosphoric acid .. | ·64 |
| Lime | 30·05 |
| Magnesia | 16·72 |
| Sulphuric acid | 42·60 |
| Chlorine | ·90 |
| Soluble silica | ·06 |
| Fluorine | traces. |
| Alkalies and loss | ·54 |
| | <hr/> |
| | 100·00 |

This incrustation did not contain a trace of carbonate of lime or magnesia, two constituents always present in ordinary boiler incrustations.

Supposing the chlorine found to be present as chloride of sodium, and uniting sulphuric acid with lime, we obtain the following results:—

| | |
|--|--------|
| Moisture (left at 212°) | 1·01 |
| Water of combination | 7·48 |
| Oxides of iron and alumina, and traces of phosphoric acid | ·64 |
| Sulphite of lime | 72·42 |
| Lime (probably present as fluoride) | ·25 |
| Magnesia | 16·72 |
| Chloride of sodium | 1·48 |
| Soluble silica | ·06 |
| | <hr/> |
| | 100·00 |

The water of combination found in this analysis is just sufficient to form, with the magnesia, hydrated oxide of magnesia; for 16·72 of magnesia require 7·52 of water, which agrees closely with 7·48, the amount found in the analysis.

It thus appears that this incrustation consists mainly of anhydrous sulphate of lime and magnesia-hydrate.

On the Possibility of Manufacturing Nérolis in the British Colonies.

By Dr. J. E. DE VRIJ.

After his arrival in Java the author found there existed in Bandoug many thousand shaddock trees (*Citrus decumana*):

In higher localities like that of Bandoug, where the average temperature is much lower than in Batavia, the fruit of the shaddock has only the size of an ordinary orange, and is not eatable. As the many thousand shaddock trees growing in the

neighbourhood of Bandoug were therefore almost useless, he thought it interesting to make some experiments on the preparation of the essence of shaddock flowers.

After a great many distillations of several hundred-weights of fresh flowers, the result was that the average quantity of essence yielded by 1000 lbs. weight of fresh flowers was 1 lb.

Having ascertained the amount of product, the following question arises:—Is the essence obtained by me from the *petala* of the shaddock trees identical with the essence of orange flowers called *néroli*? The result of his experiments in this direction was, that the two essences are really identical, which conclusion was afterwards confirmed upon his return to Europe, by the principal manufacturers of perfumes whom he consulted on this subject, and who declared the essence of shaddock flowers prepared by him to be identical with first-rate quality of *néroli*.

Another question of importance also arises:—Would the manufacture of *néroli* in the tropical countries pay? This can only be answered by practical experience. In Java, where the author made his experiments, the local circumstances are such that the manufacture would certainly pay.

But besides the *néroli* obtained by distillation of the flowers, there remains in the still after the distillation a substance which deserves attention, if ever his plan of preparing *néroli* in the tropical colonies should be carried out. If the residue in the still is thrown, yet boiling, upon a cloth, the clear yellowish liquid which passes through the cloth deposits after a few days a large amount of yellow crystals.

His experiments with these crystals have proved that they are identical with the substance discovered in 1828 by Lebreton in unripe bitter oranges, and called by him "*hesperidine*." This *hesperidine*, which the author finds very widely spread in the genus *Citrus*, is the pure, bitter substance contained also in orange peels. As this *hesperidine* is a pure and quite innocent bitter substance, which can be obtained easily, and in tolerably large quantities from shaddock flowers, it deserves, perhaps, attention as a substitute for hops.

On the Rotatory Power of several Essential Oils. By J. E. DE VRIJ.

The author communicated the results of his experiments on the rotatory power of more than ninety specimens of different essential oils. He observed them in a tube of 100 millimetres length with Biot's polarizing apparatus, and although he found a great discrepancy in the rotation of specimens of the same essential oil prepared in different localities, he considers, nevertheless, the accurate determination of this physical property of great importance for the study of these still very imperfectly known compounds. In observing, for instance, the rotation of seventeen specimens of the essence of peppermint manufactured in England, France, Germany, Holland, and America, by well-known manufacturers, he found thirteen specimens showing a rotation to the left, varying between 4° and -34° , three specimens showing a right rotation varying between $+9^{\circ}$ and $+19^{\circ}5$, and one specimen which showed no rotation at all. It appears therefore that the essence of peppermint is a mixture of at least two essences, one of which has a right and the other a left rotation, which explains the difference, and also the absence of rotatory power in different specimens. In examining the rotatory power of French and American essence of turpentine and of their compounds with hydrochloric gas, he observed the singular fact that, though both the essences showed a left rotation, the solid and liquid camphor obtained by hydrochloric gas from the American essence showed a *right* rotation, whilst those compounds obtained from the French essence retain the original *left* rotation of the essence from which they are prepared.

W. WHITE exhibited Photographs of the Interior of the Great Pyramid taken with the Magnesium Light by Prof. C. Piazzi Smyth.

On the Aniline Process in Photography. By W. WILLIS.

On the New Formulæ, with reference to Schools and Examinations.

By Dr. T. WOOD.

Dr. Wood said he wished to call the attention of the Section to a matter which

was giving to chemistry a repulsive aspect, and which rendered the passage even of the outer gate difficult to those who wished to enter its domains; namely, the two systems of nomenclature at present in use amongst chemists.

He wished to call attention to a question of every day occurrence and of great practical importance, namely—what kind of chemical notation shall be taught to boys at school? That since the requirements of the Chemical Examiners were not alike, arose the question of not so much “What shall we teach?” as “How shall we teach it?” He hoped that the discussion of these questions would lead to some definite result; which would be of great weight and value as bearing the sanction of the Chemical Section of the British Association,—a result much to be desired, as the inconvenience at present suffered by many teachers from the present unsatisfactory state of things was very great.

He called attention to the inexpediency of printing any book, intended as a text-book for beginners, with the old and new formulæ side by side.

1st. He found by practice that the old formulæ are more easily understood than the new; and even when a student was told to learn only one, he generally read both, and frequently ended by understanding neither.

2nd. That it is difficult to teach the new formulæ to students who know something of the old, especially if the text-book contains both; and more so when the student is not a constant attendant in a laboratory.

3rd. That in order to teach the new symbols successfully, sets of text-books containing the new symbols only must be used, especially for school-boys.

It is of great importance that those who have to teach in schools, should know not merely what to teach, but have some general understanding or common consent as to the terms and language in which their instruction is to be conveyed; and further, have some authoritative sanction for so strong a measure as the introduction of new symbols before their use is generally required. With this view the following questions are submitted:—

1st. Are the new symbols really essential? Are the advantages gained practically so great as to demand the sacrifices required by the change?

Physicians, tutors, and others not professed chemists' who have a respectable knowledge of chemistry according to the old system, will find themselves unable to comprehend and teach the new, without a fresh course of chemical study.

2nd. If the new symbols are really necessary, they ought to be taught at once to all persons beginning to learn chemistry; above all, to boys.

3rd. From what has been before stated, it follows that if the new formulæ are to be used in schools, books written with the old formulæ are useless as school-books. This is a difficulty which may be overcome by the issue of new editions, but publishers no doubt will look with suspicion on books treating of a science which can deal with such wholesale reform, and writers with unsold editions would be in an evil case.

It will of course require some authoritative enunciation before people will quietly turn aside from their books, old friends, the companions and assistants of years, and see their places taken by younger and newer productions with which they feel little in common; and they will heave many a sigh to think that a change so small in apparent good, should cause them so much trouble and annoyance. It will not be at the desire of a single examiner or professor that a master will allow his pupils to learn new symbols, or agree to banish the old class-books and order new ones. There is therefore much to be considered in the proposed change.

GEOLOGY.

Address by Sir RODERICK I. MURCHISON, K.C.B., G.C. St.A., D.C.L., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey, and President of the Royal Geographical Society, President of the Section.

LADIES AND GENTLEMEN,—Gratefully remembering the cordiality with which the men of science were received here in the year 1839, and again in 1849, and

knowing how much our objects were advanced on both those occasions, it gave me the sincerest pleasure to propose last year at Bath, that a meeting of the British Association should be held, for a third time, in the town of Birmingham.

Intimately connected as I have been with the British Association since its foundation in 1831, when, as the then President of the Geological Society, I headed the small band of my London associates who assembled at York, you will believe me when I say that it affords me the highest gratification in my old age to preside once more over my brother geologists, particularly in this flourishing town, so near some of the most instructive and attractive of the Silurian districts.

It is now nineteen years since I presided over the British Association; and fifteen years have elapsed since I occupied the geological chair; for, although I have not in the mean time ceased to use my hammer, and though I still cling as keenly as ever to this my own special science, I have, in what I consider its enlarged sense, been led to endeavour to advance, in late years, by every means in my power, the sister science of Geography. I have thus had the happiness to see that, whilst the comparatively new Section of Geography and Ethnology has become very popular, and is always crowded, at all our recent meetings Section C treating, as it does, of the true foundation of geography, has been quite as well attended as ever; and I trust that on this occasion our room will be as well filled as it has ever been in previous years, when this Section was presided over by a Buckland, a Sedgwick, a Delabèche, a Lyell, and a Phillips.

Great indeed have been the advances made in geological science in the sixteen years which have elapsed since our last meeting in Birmingham. For although at that time the bases of the classification of the older rocks were then firmly established, still our knowledge of the correlations and contents of the several formations ascending from the oldest stratified rocks in which we could distinguish the remains of life has since been materially extended.

The lowest sedimentary rocks, which, with most geologists, I considered to be azoic, or void of life, simply because at that time nothing organic had been discovered in them, have, through the labours and discoveries of Sir William Logan and his associates in Canada, been found to contain a Zoophyte, which they termed *Eozoon Canadense*. The rocks containing this fossil were named Laurentian by Logan long before that fossil was detected in them, and simply because they clearly underlie all the rocks of Cambrian and Silurian age. On the same principle of infraposition, it was my good fortune to be able, in 1855, to point out the existence of these same ancient rocks on a large scale in the north-west Highlands of Scotland: and though I at first termed them Fundamental Gneiss, as soon as I heard of Logan's discovery in North America I adopted his name of Laurentian.

In our islands, however, nothing organic has been discovered as yet in these our British fundamental rocks, though they are truly of Laurentian age. For although it was supposed for a moment that the rocks of the Connemara district in the west of Ireland were also of that high antiquity, because it was said that they contained an *Eozoon*, I assert, from my own examination*, as well as from information obtained during a recent visit by Professor Harkness, that the quartzose, gneissose, and calcareo-serpentinous strata of the Bins of Connemara, in which the supposed *Eozoon* was said to exist, are simply metamorphosed Lower Silurian strata. Professor Harkness will explain this point to you, and will further, I believe, endeavour to convince you that there is no organic structure whatever in the serpentinous rock of Connemara. But, whatever may be the decision of microscopists, I must, as a geologist, declare that, inasmuch as Zoophytes of a low order (Foraminifera) unquestionably occur in Laurentian rocks, so it was by no means improbable that the same group of low animals, having, as far as we can detect, no antagonistic contemporaries, and having been, therefore, free from any "struggle for existence," might have continued to be the inhabitants of sea-shores and cliffs during the long succeeding epoch.

The mere presence of an *Eozoon* is therefore no proof whatever that the rock in which it occurred is of the "Fundamental" or "Laurentian" age, that point being only capable of settlement by a clear infraposition of the rocks to well-known

* See 'Siluria,' p. 190.

and clearly defined Lower Palæozoic deposits, in the lowest of which, or the Cambrian of the Geological Survey, another form of low Zoophyte, and a few worm-tracks have, as yet, alone been detected.

In a word, this discovery of a Foraminifer in the very lowest known deposit, instead of interfering with, sustains the truth of that doctrine which all my experience as a geologist has confirmed, that the lowest animals alone occur in the earliest zone of life, and that this beginning was followed through long periods by creations of higher and higher animals successively. Thus, through the whole of the vastly long Lower Silurian period, so rich in all the lower classes of marine animals, whether Mollusks, Crustaceans, or Zoophytes, no one has yet detected a vertebrated creature. Fishes first begin to appear in the latest Silurian deposit, from which time to the present day they have never ceased to prevail; and new forms of Vertebrata, adapted to each succeeding period, have followed each other. Every geologist knows how, in the overlying Secondary and Tertiary formations, higher and higher grades of animals successively appear, and how the relics of man or his works have been detected in the youngest only of the Tertiary deposits, though certainly at a period long anterior to all history. We now well know that human beings coexisted with quadrupeds which are extinct; and we also know that the physical configuration of the surface has undergone considerable changes since such primeval men lived. This subject, opened out in France by M. Boucher de Perthes, followed by some of his distinguished countrymen, has in our country received much illustration at the hands of Prestwich, Lyell, Falconer, Lubbock, Evans, and others, and is now a well-established doctrine.

But the great feature at the other end of the geological series, to which I revert, is the uncontradicted fact, which has been passed over by many writers, or misrepresented by others, that there were enormously long periods, following that of the primeval zoophytic deposits, during which the seas, though abounding in all the other lower orders of animals, were not tenanted by Fishes.

As this is a fact which the researches, during thirty years, of many geologists, amidst the Lower Silurian rocks in all parts of the world, have been unable to invalidate, so it teaches us, in our appeal to the works of nature, that there was a beginning as well as a progress of creation, and that those writers, however eminent, who have announced that Fishes, Mollusks, and other Invertebrata appeared together, have asserted that which is positively at variance with the results of the researches of this century. As I have in various works pointed out this great fundamental principle in the origin of successive faunæ, and as at my age I may probably never again occupy a geological chair, I hope therefore to be excused for looking back with some pride, now that I am on the eastern borders of my Silurian region, to the period when, thirty years ago, I dwelt on the then novel fact, never since contravened, that "the Fishes of the Upper Silurian rocks appeared before naturalists as the most ancient beings of their class"*. Enormous regions in Europe and America over which these Silurian rocks extend have, I repeat, been long harried, with an intense desire on the part of many searchers to find something which would gainsay the datum-line that marks the beginning of vertebrated life; and, as all these efforts have failed, I have some right to insist upon the value of such a vast amount of what those who seek to oppose this view still persist in calling negative evidence. The facts however remain, and on them I rest my belief.

In this short introductory Address I cannot attempt to present to you a sketch of the general recent progress of geological science in other parts of Europe or in America. This must be sought in the well-digested recent Address of the actual President of the Geological Society, Mr. W. J. Hamilton. I must, for the most part, confine my observations to certain British questions, the more so as I know that our distinguished associates of other countries, who honour us by their presence on this occasion, come to us mainly for the purpose of ascertaining the progress we have made in our isles, and also with the view of visiting those of our typical localities of which they have read.

* See 'Silurian System,' p. 605. Though the work was not published until 1838-39, the Silurian system and its characters were established by me in 1835 (see 'London, Edinburgh, and Dublin Philosophical Magazine,' 3rd series, vol. vii. p. 46, 1835).

Among those visitors from abroad, I must first allude to my eminent friend, M. Henri von Dechen, the Nestor of living geologists in Prussia. In speaking of him, I turn back to the year 1827 (four years before the foundation of the British Association), when he and his associate Oeynhausien explored our islands, and when it was the good fortune of Professor Sedgwick and myself to examine parts of the Highlands of Scotland in company with those able young German geologists, who have since risen to such high distinction. Of him who is now present I will only say that the great geological map of the Rhine Provinces, of which he has been the director, is a work of special value to English geologists. In this map are delineated with precision the whole series of the stratified rocks on both banks of the Rhine, from those Devonian limestones of the Eifel which were correlated with our own by Sedgwick and myself, to the Coal-measures and the several Tertiary and superficial deposits, as well as all the rocks of igneous origin; in it are also elaborated in the most skilful manner all the numerous intermediate strata, of Devonian and Mountain-limestone age, which are wanting in the immediate vicinity of Birmingham, but which have to a great extent their equivalent representatives in other parts of our islands. Whilst for the subordinate strata thus delineated M. von Dechen and all Prussian geologists naturally employ local names, I am glad to find that the general groups of Silurian, Devonian, and Carboniferous are thoroughly recognized by him and his associates according to the divisions established in Britain, and of which our father William Smith set the first example, by his admirable identification of the strata of the Secondary rocks by their fossils and order of superposition.

My veteran German friend is accompanied by another of his countrymen, Professor Ferdinand Roemer, of Breslau, whose works have justly earned for him a very high position, particularly in paleontology; and whilst one of these is upon Texas, in the United States of America, let me say how fortunate we are in having among us Principal Dawson, of Montreal, in Canada, whose high merits are so well known to every reader of the volumes of Lyell and the Quarterly Journal of the Geological Society of London. There may indeed be present several distinguished visitors from distant countries, with whose arrival or intention of coming hither I am unacquainted whilst I write; but in relation to our nearest neighbours, the French, it gave me great pleasure when I learned that our younger Foreign Associates were to be led by M. A. Gaudry, once President of the Geological Society of France. Now, all these visitors will, I doubt not, rejoice in having the opportunity of studying the varied relations of the sedimentary and eruptive rocks in the vicinity of this flourishing hive of human industry. These and other foreign visitors, as well as our associates from different parts of the United Kingdom, will necessarily take a deep interest in comparing the varied rocks and their fossils which are grouped around our place of meeting, with the sedimentary and eruptive rocks of their own several districts.

Among the recent important additions to our knowledge of the geographical distribution and characters of the Silurian rocks, I cannot but advert to the successful labours of Professor Harkness. He had already shown in the clearest manner, by the evidence of fossils and order of succession, that the lowest of the strata in the Cumbrian district of the Lakes, the slates of Skiddaw, are truly of Lower Silurian age, and not older than the Llandeilo group. Recently, in pursuing his labours, he has detected fossils in the "green slates" or volcanic ashes and porphyries which lie intermediate between the Skiddaw strata and the higher Silurian; and he has further found others in the Coniston Flags, which he views as equivalents of the upper part of the Caradoc formation. Further, Professor Harkness has shown, for the first time, that the slaty rocks of Westmoreland, which separate the Carboniferous limestone from the Permian of the Vale of the Eden, contain Lower Silurian fossils similar to those of Cumberland. I hope also to learn from him at this meeting what has been the effect of certain great faults ranging from north to south, which have impressed a grand and picturesque outline on that region, and upon the lines of which are situated the most striking of the lakes of the north-west of England.

Although no Lower Silurian rocks, properly so called, occur near Birmingham, one adjacent tract, the Lickey, offers a characteristic example of the lowest of the

Upper Silurian rocks, in the form of quartz-rock; whilst the limestones and shales of Dudley, and their beautiful fossils, surmounted by those of Sedgeley, are very rich, and characteristic of part of the overlying Ludlow and Aymestry series. I am glad to find that the members of the Dudley and Midland Geological Society will not only communicate to us papers on the different organic remains of these deposits, but will also point out the relations of these rocks to others in the west, where the whole Silurian system is more fully developed. We shall also, I hope, have fresh illustrations of the effect of the eruptions of the basaltic and igneous rocks of the Rowley Hills, and other similar bosses, upon the Palæozoic strata which they penetrate.

Above all, the mining public and proprietors in the Midland Counties will, I am certain, be well instructed by the evening lecture to be given by my friend and associate Professor Jukes, who so distinguished himself, by his descriptions and maps of this his native district, as justly to entitle him to be placed at the head of the Geological Survey of Ireland, which for many years he has conducted with great ability. He can, no doubt, indicate to you the extent to which profitable works in coal are likely to be carried out, by sinkings through that Lower Red Sandstone of the central counties which is now termed Permian, a name proposed by myself in 1841, as taken from a large province in Russia, because I there found sandstones and limestones of the same age, extending over a region much larger than France. The sinkings, which were successfully made through this deposit at Christchurch by the late Earl of Dartmouth, only four miles to the west of Birmingham, induced me, twenty-seven years ago, to write thus:—"It is, indeed, impossible to mention this enterprise without congratulating geologists on the effects which their writings are now producing on the minds of practical men, since it was entirely owing to inferences deduced from geological phenomena that this work was commenced, whilst its success was derided by many of the miners of the adjacent coal-field."

If that enterprise has not been extensively followed, we must recollect that, to sink shafts to depths of many hundred feet can in central England scarcely be profitable, so long as coal is found so much nearer the surface, as in the South Staffordshire field; yet, as that field is tending towards exhaustion, it is cheering to know that extensive beds of coal will be worked in future ages under some of the red lands of the Midland counties and the Magnesian Limestone of Nottinghamshire, under which the great Derbyshire coal-field passes; and hence all present estimates of the duration of our coal-supply must be more or less fallacious, if such high probabilities be left out of the estimate. At the same time it must be admitted that we are consuming this staple of our national greatness at so rapidly increasing a ratio, that the value of the warning voice of Sir William Armstrong at the Newcastle Meeting of the Association, when he told us that, with a continued yearly increase of two millions and three-quarters of tons, our coal-supply would in many tracts be exhausted in little more than two centuries, is well sustained*. Now, when this announcement was made, the average total annual produce, as ascertained by the Mining Record Office of the Museum of Practical Geology, amounted to 86 millions of tons; but by the estimate of last year, as prepared by Mr. Robert Hunt, and to which I have recently affixed my name, the produce has risen to the astounding figure of 93 millions of tons. Such is our own natural industry and enterprise that not more than 9½ per cent. of this enormous quantity is exported for the use of foreign countries, among which France receives but 1,400,000 tons per annum.

Passing from the consideration of these deep-seated subjects to the superficial deposits of the country around Birmingham, I would advise any of my associates who have not witnessed the phenomena to repair to the parishes of Trescott and Trysull, and the adjacent hills to the west of Wolverhampton, there to see a quantity of blocks of granitic and other hard northern rocks, all foreign to the district, which were evidently carried by icebergs floating in the sea which covered this flat and undulating region in the heart of England during that glacial period when Scotland was what Greenland is now—an ice-clad region,

* Mr. Edward Hull, of the Geological Survey, in his valuable work the 'Coal-fields of Great Britain,' had previously developed the resources of those fields, and had replied to the oft-repeated question, "How long will our coal-fields last?"

whence icebergs, transporting blocks of stone, were floated southwards* from great Scottish glaciers which protruded into the sea.

Coming hither in ignorance of what the several associations of local geologists (which rival each other in their researches) have accomplished, I shall be happy to learn that some of them have detected, in this portion of the kingdom, any of those proofs of the existence of man at an early period, when large animals, now extinct, prevailed in our islands, in ages so remote that, since then, the physical configuration of the country has undergone considerable changes. This inference is, as I have said, founded upon irrefragable evidence collected in different parts of Europe, as well as in our own country. When, however, we come to consider the *modus operandi* by which these great physical changes have been brought about, geologists have different opinions. As one who holds to the belief, that in former periods the crust of the earth was from time to time affected by an agency much more powerful than anything which has been experienced in the historic era, I do not believe that the wear and tear due to atmospheric subaërial erosive agency could, even after operating for countless ages, have originated or even have deepened any of the valleys and gorges which occur in countries as flat as the tract in which we are now assembled.

But whilst I adhere to my long-cherished opinion as to the great intensity of power employed in the production of dislocations of the crust of the earth, and though I cannot subscribe to the doctrine that the ordinary action of deep seas remote from coasts can adequately explain the denudation of the old surface, even by invoking any amount of time, I recognize with pleasure the ability displayed by my able associates, Ramsay, Jukes, and Geikie†, in sustaining views which are to a great extent opposed to my own in this department of Theoretical Geology.

Admiring the Huttonian theory, as derived from reasoning upon my native mountainous country Scotland, and fully admitting that on adequate inclines ice and water must, during long periods, have produced great denudation of the rocks, I maintain that such reasoning is quite inadequate to explain the manifest proofs of convulsive agency which abound all over the crust of the earth, and even are to be seen in many of the mines in the very tract in which we are assembled. Thus, to bring such things to the mind's eye of persons who are acquainted with this neighbourhood, I do not apprehend that those who have examined the tract of Coalbrook Dale will contend that the deep gorge in which the Severn there flows has been eaten out by the agency of that river, the more so when the deep fissure is at once accounted for when we see the abrupt severance that has taken place between the rocks which occupy its opposite sides. In that part of Shropshire, the Severn has not worn away the rocks during the historic era, nor has it produced a deeper channel, whilst in its lower parts it has only deposited silt and mud, and increased the extent of land on its banks.

Then, if we turn to the district in which we were last assembled, the valley at Bath is known to be the seat of one of those disturbances to which my eminent friend Sir Charles Lyell candidly applied the term "convulsion"; the hot waters of that city having ever since flowed out of a deep-seated fissure, clearly marked by the strata on the one side of the valley having been upheaved to a height very different from that which they once occupied in connexion with those of the other side. When, indeed, we look to the lazy-flowing, mud-collecting Avon, which at Bath passes along that line of valley, how clearly do we see that it never scooped out its channel; still more, when we follow it to Bristol, and observe it passing through the deep gorge of Mountain-limestone at Clifton, every one must then be convinced that it never could have produced such an excavation. In fact, we know that, from the earliest periods of history, it has only accumulated mud, and has never worn away any portion of the hard rock.

† See 'Silurian System,' p. 535.

* The work of Geikie, recently published, and entitled 'The Scenery of Scotland viewed in connexion with its Physical Geology,' is an admirable illustration of that author's descriptive powers. Though I am opposed to his view of the original formation of valleys and deep depressions by rivers and the atmosphere, I quite agree with him as to the great effect produced by glaciers when that mountainous region was covered by snow and ice.

From such data I conclude that we cannot apply to flat regions, in which water has no abrading power, the same influence which it exerts in mountainous countries; whilst we are also compelled to admit that the convulsive dislocations of former periods produced many of those gorges in which our present streams flow. To pass, indeed, from the environs of Bath and Bristol, and even from the less distant Coalbrook Dale, you have only to contemplate the tract which lies between Birmingham and Dudley, and endeavour to satisfy the mind as to the processes by which it has been planed down before the surface was covered by the Northern Drift; for the great dislocations which this tract has undergone, as proved by many subterraneous workings, must have left a highly irregular surface, which was so levelled by some very active causes as to obliterate the superficial irregularities corresponding with the interior disturbances. In short, what was this great power of denudation which took place in a tract where there are no mountains whence powerful streams descended, and in which there are no traces of fluvial action? Must we not, in candour, admit that such denudation is as difficult to account for as it is to explain by what possible gradual agency the vast interior of the valley of elevation of the Weald of Sussex and Kent, and that of the smaller valley of Woolhope in Herefordshire, have been so absolutely and entirely denuded of every fragment of the enormous masses of debris which must have encumbered these cavities, as derived from the rocks which once covered them? Placing no stint whatever on the time which geologists must invoke to satisfy their minds as to the countless ages which elapsed during the accumulations of sediment, I reject as an assumption which is at variance with the numberless proofs of intense disturbance, that the mechanical disruptions of former periods, and the overthrow of entire formations, as seen in the Alps and many mountain-chains, can be accounted for by any length of action of existing causes.

But I must not wander further on, illustrating this principle, to which, as an old practical geologist, I firmly adhere, namely, that in former periods there existed forces which, though similar in kind, were of much greater intensity than those which now prevail, and without which we in vain seek to account for the upheavals, depressions, dislocations, and even many of the denudations of which the old crusts of the earth exhibit such undeniable proofs.

To turn, however, from these general views to the immediate prospects of this Meeting, I must congratulate you on having here among the men of science many of the good geologists who constitute the Natural-History Clubs, most of which have arisen since the British Association met last at Birmingham.

First in the number of such local associations let me mention the Club of the Malvern Naturalists, so ably presided over by the Rev. W. Symonds. Many are the valuable data which the researches of its president and members have brought to light, in addition to the original sketches of that highly interesting tract by Mr. Leonard Horner and myself, and to the more elaborate and finished work of Professor Phillips. Among the last contributions, I must specially advert to a memoir by Dr. Holl, in which he endeavours to prove that the lowest crystalline rock of the Malvern Hills is the equivalent of the Laurentian system of North America. Although I was at first indisposed to admit the validity of his inference, and even yet see objections to it, and incline rather to the belief that it is of a Lower Cambrian age, I deem it fair to avow that, in a tract where all the lowest Silurian rocks are exhibited, though in epitome only, it is possible that the basement of that primitive Malvern series may be the equivalent of the vast Laurentian of America, the north-west of Scotland, and of Bohemia, though in mineral character there is not the resemblance I should expect to find.

Then in Shropshire, the very kernel of the Silurian rocks of Britain, we have the Caradoc Club, continually adding to and illustrating all the phenomena around the Wrekin and Caer Caradoc; and the Oswestry and Welshpool Naturalists' Club, whose Secretary is a zealous geologist, and, with his associates, diligently explores the neighbourhood of Oswestry and Llangollen, to the geology of which he has recently published a 'Guide.' In Herefordshire there is the Woolhope Naturalists' Club, whose members claim, and occupy with zeal, all the fossil hunting-ground to the south of the Caradoc, and range in their excursions from the beautiful valley of elevation at Woolhope to Ludlow and its environs.

Next, if we cross the valley of the Severn, or that which, in the geological

language used in former years, I ventured to term the "Straits of Malvern," and ascend from the valley of the Severn, occupied by New Red Sandstone and Lias, we have the Cotteswold Club, the labours of which have already thrown much light on the composition and fossil contents of the Oolitic formations. And lastly, to make out three-fourths of a scientific-field circle around Birmingham, there are at Warwick a Museum and a Field Club vigorously led by the Rev. P. B. Brodie. Now most of these institutions have local museums, some of them of value; and that of Dudley in particular rivals the collections of this opulent town.

With such means and appliances, then, as surround Birmingham, to say nothing of the great support we shall have from abroad and from numerous parts of our islands, I have no doubt that the proceedings of the Geological Section of this meeting will equal those of any former gathering. Above all, as geologists, we are inspired and honoured by the prominence which has been given to our science in the fact, that as the last meeting was presided over by Sir Charles Lyell, so we are now assembled under another of our eminent leaders, Professor Phillips, whose untiring labours, blended as they have always been with the heartiest goodwill and the kindest manners, have, from its origin to the present day, been the mainstay of the British Association for the Advancement of Science.

The Economic Value of the various Measures of Coal and Ironstone in the South Staffordshire Coal Field. By S. BAILEY.

On the Fossiliferous Beds of the New Red Sandstone (Upper and Lower Keuper) in Warwickshire. By the Rev. P. B. BRODIE, M.A., F.G.S.

The prevailing fossils in these two divisions of the Trias were described, especially the remains of cestraciant fishes, more perfect than usual in the Upper Keuper; a species of *Palæoniscus* (*P. superstes*), the last of its race, and a new mailed fish undescribed, closely resembling some from the Old Red Sandstone; with plants profusely distributed in certain places, indicating a somewhat varied flora, and especially well-defined footsteps of *Rhynchosaurus* (noticed here for the first time in the Upper Keuper) and *Labyrinthodon*, chiefly confined in Warwickshire to the higher division. The Lower Keuper is remarkable for its more or less perfect remains of *Labyrinthodonts*, of which a fine collection, the best in England, is contained in the Warwick Museum. Hence it was shown that predaceous fishes and Salamander-like reptiles were comparatively abundant during this period; and if this formation was as largely quarried as many others, a more extensive fauna and flora would probably be detected. A greater extension * of the Keuper was pointed out in a portion of the area occupied by it, while it reached its minimum thickness in Warwickshire, as shown by Mr. Hull. The best sections of the Upper Keuper were described in detail, and the denudations which the district under review had undergone were accurately determined.

On a Section of Lower Lias at Harbury, near Leamington.

By the Rev. P. B. BRODIE, M.A., F.G.S.

In the first paper the author described in detail the section of the 'Lima beds' exposed on the line of the Great Western Railway, which contain the usual fossils, and, as far as could be measured, reach a thickness of 40 feet, to which, if the lowest shales could be added, a greater thickness would be attained. Below the Lima beds the White Lias appears cropping out on the west, where in some places in the neighbourhood it is largely quarried, passing downwards into the Rhaetic series, which is partially indicated by the occurrence of a sandy stone with *Estheria minuta*, the whole overlying the red marl. The Lima beds here agree pretty well with the same zone in Gloucestershire, Dorsetshire, and Somersetshire, though this section cannot be so clearly correlated with the still finer one seen in the railway-cutting at Saltford, near Bath. It is to be noted that at Harbury the 'Insect or Saurian beds,' intermediate between the Lima beds and the White Lias, are so much reduced in bulk that they are most feebly represented.

* This has been omitted in the last Survey Map of the district.

*On two New Species of Corals in the Lias of Warwickshire.**By the Rev. P. B. BRODIE, M.A., F.G.S.*

The author observed that an unusually large species of *Montlivaltia**, as yet undescribed, had been met with in the Middle Lias, near Shipston-on-Stour, where it is abundant, the largest specimens measuring 5 to 6 inches in length, and 3 in diameter across the calicular surface, varying in size and form, some being more elongated and others more cyathiform. Most of the corals are unfortunately much weathered, the epitheca being rarely preserved, but better ones might be obtained by quarrying. One example of the so-called *Montlivaltia Haimeii* was described from the Lower Lias, near Rugby. Though abundant in Nottinghamshire, it is rare in Warwickshire, and is known also in Ireland, where it was first observed by Mr. Tate. It may perhaps be questioned whether this coral is correctly assigned to the Belgian species. Of late years the number of British Liassic corals has greatly increased, and when all are published and described, the list will certainly equal, if it does not exceed that already known in foreign countries.

Remarks on the Drift in part of Warwickshire, and on the Evidence of Glacial Action which it affords. By the Rev. P. B. BRODIE, M.A., F.G.S.

The extent and character of the low-level drift round Warwick and Leamington and along the valley of the Avon, were first described, containing in places the usual mammalian remains, but no flint implements had yet been detected. Of older date belonging to the glacial period, was an extensive deposit of drift occupying the high table-land over an area from 6 to 12 miles N.N.W. and W. of Warwick. Rounded pebbles and boulders of various size and diverse mineral composition are scattered in greater or less abundance over the whole of this tract, including granite (rarely) and other more ancient rocks. Here and there some large erratic blocks are met with, but generally the pebbles are of small size, consisting mostly of sandstone and quartz. Flints little abraded are nowhere absent from this drift, though more abundant at some spots than others. Fossiliferous rocks are very scarce, but at one place pieces of chalk rounded and scratched with flints, greensand, oolite, lias, magnesian and mountain limestone, and rounded boulders of older formations were indiscriminately mingled together. Hence it was inferred that an iceberg had deposited a portion of its load there. The other erratics consist of the usual detritus, supposed to have been derived by the same means from the north generally, though much of it may have been transported from other directions. The most novel and interesting fact was the discovery of *Orthis redux*, *Lingula Lesueurii*, a species of *Modiolopsis*, and *Trachyderma serrata* in the quartzose pebbles and sandstones, identical with those figured and described by Messrs. Salter and Vicary in the Quart. Journ. Geol. Soc., from the New Red Sandstone at Budleigh Salterton in Devonshire†. It was inferred that these numerous pebbles of a similar lithological character had the same origin as the Devonian ones, and that in all probability the upper red sand and marls with pebbles once capped the Keuper in Warwickshire, and the softer material having been denuded, the heavier masses were scattered about as they are now found. The few fossils hitherto found in them by the author are at all events Lower Silurian species belonging to the Armorican sandstone, and the quartzites of Ivray in Normandy.

A list of some of the chief constituents of the drift was appended, showing its prevailing contents to be of a very mixed character, though the sandstone and quartzose pebbles largely predominate.

Organic Remains of the Coal-Measures. By L. P. CAPEWELL.

* It appears that this species occurs in the Lias on the Continent, where it was described by Fromentel et Ferry, under the name of *Montlivaltia cuneata* = *M. Cherringtonensis*, Duncan, MS.

† These shells were examined and identified by Mr. Woodward, Mr. Salter and Mr. Vicary at the late Meeting of the British Association in Birmingham.

On the Fossil Plants of the Post-Pliocene Deposits of Canada in Connexion with the Climate of the Period, and the Formation of Boulder Clay. By Principal J. W. DAWSON, LL.D., F.R.S.

The author said the leading deposits are, in descending order, the Saxicava-sand and Leda-clay, and the Boulder-clay; but the latter, though locally under the Leda-clay, is of various ages. Instances were referred to of boulder deposits older than the Leda-clay, contemporaneous with this and the Saxicava-sand, and also later than either. Many arguments were adduced to show that in Canada the striation of both surfaces and the deposit of Boulder-clay had taken place under the influence of ice drifted by ocean currents, and that there was no evidence of any period when the continent was covered with glaciers, though these may have existed on parts of the land remaining above water in the period of depression. It was shown that the driftage had been from the north-east, or against the slope of the country; that the materials of the deposit were of such a character as to prove that they could not have constituted subaërial moraines, and that marine fossils occur in some parts of the Boulder-clay. The paper next referred to the action of icebergs in the Straits of Belleisle, and on the coast of Newfoundland, showing that their vast numbers and great size, together with their movement and frequent grounding, must enable them to produce great mechanical effects. The author quoted evidence to show that more than four hundred large bergs are sometimes acting at one time in the Straits of Belleisle, and showed that during the Post-pliocene submergence the influence of icebergs and the Arctic current must have been exercised in a similar manner over the whole of the St. Laurence Valley. The last point discussed was the nature of the flora of the Post-pliocene in Canada. The species of plants found in these deposits were noticed, and their present range stated, from which it appeared that they constitute a somewhat aërial but not Arctic assemblage, and would indicate no greater refrigeration than that which would be due to the actual subsidence proved to have occurred. This inference would also correspond with the evidence of the animal remains and with the effects attributed to the Arctic current, bearing its annual burden of ice over the submerged land.

The Succession of Palæozoic Floras in North America.

By Principal J. W. DAWSON, LL.D., F.R.S.

The Palæozoic formations of Eastern North America may be grouped in four great ages, each characterized by a distinct fauna and flora, and a corresponding series of physical conditions. These are the Lower Silurian, the Upper Silurian, the Devonian, and the Carboniferous, each of which constitutes a great cycle of palæozoic time. The rocks, supposed to be Cambrian, are imperfectly known, and have afforded no fossils. The Permian group has not been recognized.

1. The Carboniferous flora may be arranged in three subordinate groups.

(1) That of the Upper Coal formation, consisting of a few of the more widely distributed species of the Middle Coal formation. (2) That of the Middle Coal formation, the head-quarters of the peculiar Carboniferous flora and of the productive beds of coal. (3) That of the Lower Carboniferous Coal-measures, consisting of a few peculiar species, several of which are not found in the overlying parts of the system. These plants have been recently recognized at this period in Eastern America, and a similar group seems to have existed at the same time in Great Britain. The whole coal-flora in British North America may be estimated at about 150 good species, of which the greater number are common to America and Europe.

2. The Devonian rocks in Eastern America have afforded eighty-one species of land plants, of which only about ten are common to this and the Carboniferous period. They occur principally in the Upper Devonian, but some extend to the bottom of the system. Though fewer in species, the Devonian flora is not lower in grade than that of the Carboniferous period. The earliest known species are allied to *Lycopodiaceæ*. The Devonian flora has been recognized in Pennsylvania, New York, Ohio, Canada, Maine, and New Brunswick. The number of species common to the Devonian of Europe and America is not so great as in the case of the Carboniferous.

3. The Upper Silurian has afforded land plants only in its upper beds, and only at Gaspé in Lower Canada. The only well-characterized species is *Psilophyton princeps*, which is also one of the most common plants in the Devonian. The first known appearance of land plants in America is thus at the same geological period with their first known appearance in Europe.

4. The Lower Silurian has as yet afforded few land plants. It abounds in objects called fucoids, but the greater part of those are trails of worms, crustaceans and mollusks, rill-marks, shrinkage-cracks, &c. Those that show carbonaceous matter or structure seem to be allied to Northern Algae. The extent of shallow-water deposits of the Lower Silurian explored in Eastern America without any observance of land plants, would seem to afford at least a presumption against their abundance at that period.

The author anticipates that the Laurentian will yet afford evidence of at least the existence of Algae before the Paleozoic period. He has prepared for communication to the Geological Society a detailed account of that part of the above succession which relates to the Carboniferous of British America.

On the Lower Lias of Lyme Regis. By E. C. H. DAY.

On a Head of Hybodus Delabechei. By E. C. H. DAY.

On the History of the Jurassic Seas, as evidenced by the History of the first Liassic Sea. By E. C. H. DAY.

On the Large Prussian Geological Map of the Rhenish Provinces and Westphalia. By GEHEIMRATH H. VON DECHEN and Prof. E. RÖMER.

M. Geheimrath H. von Dechen, of Bonn, gave a general explanation of the large Geological Map of the Rhenish country, and of the Province of Westphalia, which is chiefly his own work, and which after twenty years of incessant labour has just now been finished. This map embraces one of the most interesting parts of Germany. Besides the Devonian strata which occupy the greater part of its area, the highly remarkable volcanic phenomena of the Eifel and of the Laacher See are contained within its limits.

The whole map was executed by order of the Prussian Government. Its scale is $\frac{1}{500,000}$. A certain number of sheets of the map were exhibited in the Section-room.

Dr. Ferdinand Römer, who has taken part in the survey of this map, made some additional remarks on the Devonian strata represented on it. The Devonian rocks of the Rhenish country exhibit the most complete and best developed series of the Devonian system which exist anywhere in Europe. The whole system is here distinctly divided into three main divisions, viz.:—1. *The Coblenz Grauwacke*, consisting of dark-coloured sandstones and clay-slates of a total thickness of at least 10,000 feet. Trilobites of the genus *Homalonotus*, *Spirifer macropterus*, *Chonetes sarcinulatus*, and several species of the genus *Pterinea*, are the most characteristic organic types. In Devonshire this lowest division of the Devonian rocks on the Rhine is very little developed, or at least very imperfectly known as regards its organic remains. A few fragments of *Homalonotus armatus*, and of *Gryphaeus (Pleuracanthus) laciniatus*, and casts of *Chonetes sarcinulatus*, from Meadsfoot sands, are almost the only documents from which the existence of the Coblenz grauwacke in Devonshire may be inferred.

2. *The Eifel limestone*, i. e. a series of limestone beds and calcareous marls which chiefly constitute the several basins in the hilly region called the Eifel, which, surrounded everywhere by the Coblenz grauwacke, appear like islands on a geological map. This Eifel limestone forms the very centre of the Devonian system, and contains that wonderful variety of fossil shells, Corals and Radiata in a beautiful state of preservation, which have made the Eifel a celebrated region to palaeontologists. This middle group of the Devonian series on the Rhine is distinctly represented in Devonshire. The limestones of Torquay, Plymouth, and other loca-

lities, and the schists containing *Calceola sandalina*, are evident equivalents of the Eifel limestone, although the number of fossil species in these Devonshire limestones is not nearly so great as in the Eifel.

3. *Goniatite and Clymenia-beds*.—This uppermost group of the Devonian series is of a more varied mineralogical composition than the two other groups; Goniatites and Clymenia are the most characteristic fossil types. On the left bank of the Rhine, in the neighbourhood of Aix-la-Chapelle and Stolberg, the uppermost part of this group is formed by schists which abound with *Spirifer Verneuilii* (*Sp. disjunctus*). In that same country these uppermost Devonian strata are immediately and conformably overlaid by the true Carboniferous or mountain limestone, characterized by the well-known forms of *Productus*, as *Prod. semireticulatus* and *Prod. Cora*. Dr. Römer concluded his remarks by observing that, although the present more exact knowledge of the Devonian rocks in the Rhenish country was the result of the labours of German geologists, it ought not to be forgotten that many years ago Murchison and Sedgwick, assisted in the palæontological department by E. de Verneuil, recognized in the Eifel limestones an equivalent of the limestone of Torquay, and so were the first who proved the existence of Devonian rocks on the Rhine.

The President, in commenting upon the great value of the large map of Von Dechen, assured the Section that he had personally tested its accuracy in several explorations of the Rhenish Provinces of Prussia, and he rejoiced to find that whilst Principal Dawson had detailed the characters of the Devonian rocks of North America, his friend H. von Dechen and Ferdinand Römer had admirably developed that triple division of these rocks into which he, in his last edition of 'Siluria,' had correlated with the Old Red Sandstone of Scotland, and its equivalent group as it exists in Devonshire.

On the Existence of Gold-bearing Eruptive Rocks in South America which have made their appearance at two very distinct Geological periods. By DAVID FORBES, F.R.S., &c.

The author believed that the gold deposits of South America had not as yet been studied with a view to determine the geological period at which the gold itself had made its appearance. The present communication was the result of observations made during seven years' travels over a large part of South America, and which had enabled him to class all the deposits of gold which he had visited under two heads, both of which could be traced back directly or indirectly to the intrusion or eruption of igneous rocks.

Under the first head belonged all gold derived from the disintegration of granitic rocks of an age later than much, if not of all of the Silurian strata, but probably not later than the Devonian period.

The largest gold washings of South America, and probably of the whole world, he looked upon as derived from this source as well as the auriferous quartz veins, as these could be traced to the proximity of the granite, and which he believed to have originated in, or been injected from the granite into the neighbouring strata, carrying the gold, which was a normal constituent of the granite itself, along with it. This granite, wherever met with, is invariably auriferous in itself; and although it would not pay to grind down granite mountains and wash out the gold in it, yet in many parts of South America, in Brazil, near Valparaiso, &c., the granite, apparently solid, was frequently decomposed *in situ* to depths of even over 200 feet, as shown frequently in the late railway-cuttings, and then it sometimes repaid the labour of washing the whole mass for the sake of the gold in it. To this class also belongs several metallic veins, injected also from the granite into the neighbouring Silurian strata, which contain gold, and are remarkable for the presence of other minerals very characteristic, as oxide and sulphides of tin, iron pyrites, copper pyrites, compounds of bismuth, tellurium, selenium, &c., many of which are seldom or never met with in later rocks.

The second appearance of gold is, however, totally distinct from the above in mineral character as well as in geological age, and results from the eruption of dioritic (greenstone) rocks composed of hornblende and felspar (without quartz),

which break through the strata even as late as those containing oolitic fossils, and consequently must be regarded as younger than the oolitic period, but, as far as researches have yet shown, are probably not posterior to the deposition of the cretaceous strata. In this case, instead of quartz veins carrying the gold from the granite into the neighbouring strata, we have veins of metallic sulphides and arsenides acting in the same manner, and find the gold imbedded in its metallic state in the compounds of sulphur and arsenic, with iron, copper, &c.; and from some unknown cause the more superficial parts of these veins appear as a rule to be much richer in gold, which by the miners is generally supposed to decrease in depth.

The minerals commonly found in these veins are not the same as in the metallic veins mentioned as also occurring with the granitic rocks under the first head, and, as far as observations have gone, the metals tin, tellurium, tungsten, titanium, selenium, &c., are never found in these auriferous veins of later date.

Nothing could be more conclusive than the totally distinct age of these two sets of auriferous eruptive rocks, which the author believes to represent the only ages at which gold has been introduced into the upper crust of the globe, and thinks it probable that this generalization may be carried into other parts of the globe, if it be not altogether universal.

On the Igneous Rocks of South Staffordshire.

By DAVID FORBES, *F.R.S.*

At the request of the Local Committee of this Section, I undertook to investigate and report upon the igneous rocks of Staffordshire, and at first had some hopes of laying before the Section, at this Meeting of the Association, a more complete report upon the chemical and mineralogical nature of these rocks. Upon getting deeper, however, into the subject, I found that all the results which I could collect from the labours of previous investigators were but of little service, and contained so many discrepancies that I was compelled to commence the investigations *ab initio*. As my time could not be exclusively devoted to this inquiry, it was evident that in the few months (from March) which would elapse before the Meeting of the Association took place this year, it would be quite impossible to do any justice to the subject, especially as the careful chemical examination of many rocks as were desirable would in itself take up some months' labour. I come forward, therefore, with the present communication simply to report progress, and to show that the investigation has not been neglected, and I trust that at the next year's Meeting of the Association I may be enabled to present a more complete and detailed communication. I shall therefore merely give a sketch of the system pursued in the inquiry, and shall leave the details until I have the honour of laying a second report before the Section.

After having collected all the published information on the subject that was attainable, of which by far the most important is contained in Mr. Beete Jukes's valuable "Memoir on the South Staffordshire Coal-Field," I found that our chemical knowledge was confined to some two or three analyses made at random, if I may so speak. The two analyses of Rowley Rag and Whiterock-trap, made by Mr. Henry, and inserted in Mr. Beete Jukes's Memoir, represent, no doubt, the exact composition of the hand specimens sent to Mr. Henry, whose skill was unquestionable; yet I have quite satisfied myself that they do not represent the composition of the rock-masses in general, and would not be such as a geologist would select to represent what he considered as a fair specimen of what the rock-mass really was.

In these investigations it is absolutely essential that the chemist, geologist, and mineralogist should go hand in hand in the inquiry. It was therefore resolved to make a personal visit to each of the principal localities where these rocks occurred, and to select carefully specimens which would fairly represent the unaltered rock-mass, distant as far as possible from the external surface, which, naturally, are invariably more or less altered by the action of air, water, carbonic acid, &c., as also from the intermixture and absorption of more or less of the surrounding strata with which they come into contact. It is quite evident that without such precau-

tions being taken it would be impossible to place any reliance in the results; yet it is well known that too often no attention is paid to this subject.

A series of specimens thus collected are now prepared, and being submitted to chemical examination, whilst at the same time to examine their mineralogical structure, sections have been carefully ground and mounted for the microscope, thus enabling rocks, which to the naked eye presented nothing but a dark, indistinct surface, as if composed wholly of but one mineral, to be at once resolved into the various minerals which actually enter into their composition. Their specific gravity was also carefully determined. It would take up too much of the time of the Section, and prove too uninteresting to go over the percentage figures of the analyses already made, or to go into the details of the methods employed in the chemical examination, especially as it is intended that these results should be laid before the Section as soon as the whole of the contemplated series of analyses are concluded, and better enable comparisons to be made between the different rocks. I may only state that rocks have been already analyzed from some seven different localities, and microscopical examinations made of about fifteen localities. Some points, however, have been satisfactorily ascertained, to which attention will be directed in a few words.

As will be seen from the map of the Ordnance Geological Survey, the bosses of igneous rock which present themselves at the surface are some thirteen in number; the most extensive of them all being the Rowley Hills, covering an area of probably about $2\frac{1}{2}$ square miles; after which the Wednesfield and Barrow Hill eruptions come respectively next in extent, whilst the remainder are on a much smaller scale. Besides, however, such rocks as are visible on the surface, the extensive mining operations for coal have disclosed numerous dykes cutting through the coal-measures and frequently forming large masses, or more or less regular sheets of hard rock, imbedded in the strata. These are generally less compact in appearance, and of a lighter colour than the larger masses, and are known to the miners of the district as "green rock," presenting some resemblance in external appearance to a greenstone, but in reality quite distinct from that rock. A third variety of igneous rock forms small dykes and veins, often very irregular, and altering both the coal and the rocks in contact with it; it is known to the miners by the appellation of "white horse," and is occasionally called white trap or felspathic trap.

I have already completed more than one chemical and microscopical analysis of each of these three varieties of igneous rocks which so often have been looked upon as different, and the results are so satisfactory as to leave no doubt but that all these rocks, however dissimilar in their present appearance, are in reality one and the same rock, or rather were originally identical, and in all probability made an eruption from one focus, and more or less contemporaneously. I cannot, however, endorse the opinion which has been expressed, that they are contemporaneous with the deposition of the coal measures, but rather am inclined to look upon them as of later date, and intruded after the consolidation of the same. For this reason also I am disposed to look upon the belt of what is termed basaltic ash, and laid down as such in the latest edition of the maps of the Ordnance Geological Survey, merely as rocks decomposed *in situ*, in part consisting of decomposed igneous rock, and in part of the decomposed, previously altered sedimentary rocks in contact with same: believing that the present Rowley Hills have been exposed and laid bare by denudation of the strata, which I suppose to have originally covered them when they were an irregular mass of igneous rock imbedded in the strata, similar to what can be seen at Pouk Hill. The apparent height of the Rowley Hills, if we look upon them as a mass of igneous rock, as they until lately have generally been regarded, is quite deceptive; the recent sinkings and cuttings having demonstrated that the igneous rock is but a superficial cap, at most of inconsiderable depth.

The Netherton canal tunnel, which has been driven through the very base of the Rowley Hills from one side to the other, has shown that this cap of igneous rock has been erupted through a dyke not more than 8 feet wide, and which was the only one cut through in driving the entire length of the tunnel, and is apparently the only channel or conduit. The terms of basalt, greenstone, trap, white-rock trap, white felspathic rock, and locally, Rowley Rag, white horse, green rock, &c., have all been applied to these igneous rocks without much discrimination, and it is

to be regretted that in England much looseness prevails in the nomenclature of the plutonic rocks. A microscopic examination of the close-grained and more compact varieties, effects completely that which the naked eye can do in the case of the more crystalline and coarser-grained rocks, and shows them in every case to be composed chiefly of a soda-lime felspar (possibly labradorite), along with a small amount of augite, and a small amount of titanoferrite or titanite iron, which is never wanting. Other minerals are but seldom present, but traces of zeolites and carbonate of lime may occasionally be found, and possibly a little olivine, though its existence is not as yet satisfactorily proved. The rock is therefore what may be termed a true dolerite, which consequently we must regard as being the sole igneous rock of the district. The presence of titanium is peculiarly constant wherever these rocks are found. However altered and decomposed their appearance may be, in the white rock, or in the red clay, on the slopes of the Rowley Hills, which proceeds from the disintegration of the igneous rock itself, there do we find the titanium, which thus furnishes an excellent guide for tracing out the connexion with the parent mass. I may mention that I have made very careful examinations to determine whether metallic iron existed in these rocks, as in the case of the rocks of the Giant's Causeway in Ireland, according to Professor Andrews, but with a negative result.

The alteration in the external appearance of these rocks, which has so long led to the supposition that they were so many distinct species, confounded under the names of basalt, greenstone, and white felspathic trap, is due in part to crystallization, in part to the action of water, and lastly, in some part also, to the fact that in the smaller veins and sheets the rock is generally found to contain somewhat less felspar and more augite, apparently for the reason that the felspar, being the less fusible mineral, has a tendency to cool and become less fluid at a temperature at which the augite is perfectly liquid. There appears, therefore, to be a greater tendency for the felspar to retain itself like a spongy agglomeration of crystals in the main mass of the rock, whilst the more fluid portion travels further into the smaller chinks and cracks of the rocks. The so-called green rock, therefore, is in general more rich in augite of a green or brown-green colour, and as it is generally much more crystalline and coarse-grained, might easily be mistaken for a greenstone, without more minute examination. Commonly, also, it is found to be more decomposed than the main mass of rock from which it has proceeded, for the reason that, having been injected between sedimentary strata, it absorbs water from these beds, or from the springs connected with them. This percentage of water is frequently found to amount to 9 per cent., without much alteration of colour, due to the oxidation of the iron present in the augite. The so-called "white rock," or "white horse," has gone a step further in decomposition—most probably due to the fact that it occurs in general in small veins or strings—and often has absorbed so much water as to be totally altered in appearance, as in the specimen here shown, which contains as much as 20 per cent. of water; and, in fact, at first sight, it looks more like a clay rock, or consolidated clay, and would not be taken for an igneous rock at all. If we, however, remember that all clays are nothing but decomposed felspar, and that this felspar constitutes, we may say, some four-fifths of the igneous rocks or dolerites here alluded to; it will be found easy to trace the change *in situ* from the unaltered dolerite to the white rock, or even to the clay, which, in its turn, is produced from the disintegration of the white rock in turn. This I have observed in several open sections, where the contact of the Rowley Rag and coal-measures are observed near Dudley; and in the diagram shown, kindly lent to me by Mr. Beete Jukes for the occasion, and which is from actual survey of Mr. Beckett, and represents the white rock as seen in section in the thick coal at the Pensnett Colliery. Here the decomposition has as yet not gone quite so far as to obliterate the peculiar concentric structure characteristic of decomposing igneous rocks of this class, well seen in the section. When in unaltered condition, the specific gravity of these rocks, when taken from the centre, or so far from the exterior as to be quite fresh, is wonderfully constant. From whatever part of the coal-field the specimen may be procured, it may be regarded as 28.4, and this agrees well with the usual titaniferous dolerites of this class met with in other countries. When altered, as might be naturally expected

from the absorption of water, the specific gravity diminishes, and may descend to 2.63 or 2.55.

The internal columnar structure and the peculiar concentric weathering of these rocks have also been the subject of special study, and the results of the observations made lead quite to disprove the evidence of any so-called globular structure in these rock-masses, but to prove that the columnar or so-called basaltic structure is due merely to mechanical causes, *i. e.*, the cooling of masses possessing a nearly homogeneous structure and subjected to the pressure of the surrounding or overlying strata; and that the development of this columnar structure is in proportion as the rock is more fine-grained and less crystalline, or in other words more homogeneous. The sedimentary strata in contact are themselves frequently so altered by contact with the igneous rocks as to present in themselves a columnar structure or jointing, in some cases quite or even more perfect than the igneous rock itself; and a bed of clay-ironstone at Pouk Hill was found jointed into regular hexagonal columns by the heating and the subsequent cooling and contraction due to the proximity to the igneous rocks which form the basis of Pouk Hill.

On a New Wealden Saurian named Polacanthus. By the Rev. W. Fox.

The author had discovered in the Wealden beds of the Isle of Wight, between Black Gang and Brooke, a new reptile of the Dinosaurian family. The only parts of the skeleton wanting are the head and neck. The animal was above 6 feet long from the shoulder to the sacrum, and was furnished with a massive tail 5 feet long. The legs were about 4 feet in length, terminating in broad short feet. This strange reptile was clothed with long armour-plates of bone, from $\frac{1}{2}$ an inch to 4 inches in diameter, and about $\frac{1}{2}$ an inch thick, that covered its body, with the exception of its back, which was protected by a great bony shield. Another remarkable characteristic of this animal was a process of spine-like bones which ran along the sides of the body and tail, some of which are 15 inches long, and in weight 7 lbs. The remains of this fossil, as well as the Wealden formation from which they were extracted, were examined recently by Professor Owen; and with reference to the extraordinary nature of the spine-like bones, Professor Owen is of opinion that the most appropriate name for this new Saurian would be *Polacanthus*.

On the Progress of the Imperial Geological Institute of the Austrian Empire. By W. VON HÄIDINGER.

A concise history of the Imperial Geological Institute was given by the Director in the opening address of the 8th of November, 1864, comprehending fifteen years since its foundation in 1849, during the reign of the present Emperor, Francis Joseph I. During this time, the geological explorations of the country have gradually proceeded, so that 155 sheets of the Austrian Ordnance maps have been geologically coloured, 110 of them in the scale of 1:144,000 (about $2\frac{2}{3}$ miles to an inch), and 45 in the scales of 1:288,000 and 1:432,000 (nearly $4\frac{2}{3}$ and 7 miles to an inch), comprising, to more or less detail, all the provinces of the whole empire. Thirteen volumes of the Jahrbuch (Annals in 8vo) have been published, as also three volumes of Memoirs in 4to. Of the copies printed (1000 and 600), no less than 800 and 340 respectively are gratuitously distributed. A library is formed, containing more than 13,000 volumes, also a considerable collection of maps, including nearly 4000 sections. The comprehensive collections of minerals, rocks, and fossils are open to public inspection in twelve rooms of the Prince Lichtenstein's palace, rented by Government for the Geological Institute.

During the year 1864, moreover, an additional set of seven sheets of maps of the north-west of Hungary was completed, as also six sheets thoroughly revised of the difficult region of the sedimentary secondary rock of the north-eastern Alps.

The geologists of the Institute were again at work in the north-west of Hungary, proceeding from the sections gained the summer before in the direction towards the east. The whole of the classical country around the ancient mining centre of Schemnitz was this time the object of exploration. Among other interesting facts, it was ascertained that the metalliferous greenstone-trachyte was superincumbent on slates of the Werfen series, with *Myacites fassacensis*, *Posidonomya Clarae*, &c.

Also other facts of undoubted superincumbence of the trachytic and basaltic rock upon certain tertiary strata, well characterized by fossils, were ascertained. Messrs. Franz von Hauer, Lipold, Foetterle, Dr. Stache, Baron von Andrian, Paul, were all engaged in this work, and beside them also a number of eight younger mining engineers. M. Wolf had to explore the neighbourhood of Töplitz for providing a sufficient supply of water for domestic purposes for that watering place, and then to continue his collections of trachytic types in Hungary and Transylvania. M. Stur had to compare collections of alpine fossils in Germany and Switzerland.

The International Agricultural Exhibition at Cologne was opened on the 2nd of June. From the Geological Institute there was sent thither a newly constructed geological map of the Austrian Empire, along with an explanatory collection of rocks and fossils. It was rewarded with the gold medal. The collection was afterwards placed in the Museum of the University of Bonn. The geological map on the scale of 1:432,000 is now in progress of being reduced to the scale of 1:576,000, in which it is to be published in twelve sheets.

A new Number of Dr. Hörnes's Fossil Mollusca of the Tertiary Vienna Basin had likewise been published in the course of the year.

Dr. Gustavus Lombe had completed an excellent memoir of the St. Cassian fossils, as also Prof. Charles Zittel, of Carlsruhe, on the Gosau Bivalves, taking as starting-points our own rich collections of them. The memoirs are printed in our Academy's Transactions. Under the superintendence of the Academy was likewise brought to light, of the Novara Publications, Dr. von Hochstetter's second volume of New Zealand, containing the Palæontology, by Unger, Zittel, Fr. von Hauer, Suess, Karrer, Stoliczka, Stache, and Gustavus Jaeger.

Additional Observations on the Geology of the Lake Country.

By PROF. HARKNESS, F.R.S., F.G.S., and H. NICHOLSON.

The Skiddaw slates, the lowest member of the sedimentary rocks of the Lake country, have hitherto afforded many peculiar forms of Graptolites, a crustacean, the *Caryocaris Wrightii*, a branching bryozoon, and tracks of worms. To these can now be added other fossils, namely, two trilobitic forms, *Agnostes Morea*, and a new species of *Phacops*. Besides these, a *Lingula* occurs in several localities in the Skiddaw slates, nearly allied to *L. brevis*. These fossils still further corroborate the inference that the lowest sedimentary rocks of the Lake District are referable to the Lower Llandeilo or Shelve group.

They are succeeded, apparently conformably, by green slates and porphyries, the former having originated from ash-beds. Hitherto these green rocks have afforded no fossils, although they have been carefully looked into. As rocks of the same position and nature occur in the north-east of Westmoreland, among which is a well-marked fossiliferous zone, the authors were induced to examine a band in the Lake country, corresponding in position with the fossiliferous zone in the north-east of Westmoreland.

This zone, which in the north-east of Westmoreland consists of dark grey flaggy rocks with distinct cleavage, lies upon a thick mass of porphyry, and is succeeded by a similar mass, separating it from the Coniston limestone, the north of England equivalent of the Bala limestone. The Lake country representative of this zone also occurs between two masses of porphyry, and consists of green slates which have been partially worked in some localities. These slates exhibit no trace of fossils when first obtained from the quarries, in consequence of the cleavage intersecting, at nearly right angles, the original bedding. On weathering, however, the lines of lamination become exposed, and among the débris of the quarries fossils are seen which have a distinct Caradoc type. One of the localities affording these fossils is Style End Grassing, in Long Sleddale, and another is to the north-west of Sunny Brow, about 3 miles south-west of Ambleside.

The rocks in the Lake district which overlie the Coniston limestone, namely, the Coniston flag and Coniston grits of Prof. Sedgwick, appear to occupy the whole of the area to the south-east of the Coniston limestone band, where Silurian rocks occur in this country, except in the neighbourhood of Kendal. These Coniston flags and grits are intersected by north-east and south-west faults, such as

those described by Prof. Sedgwick as occurring to the north of Ulverston (Aberdeen Meeting of the British Association), and the result of these faults causes these rocks to occupy a large area in the south-east portion of the Lake country. These rocks in some localities afford fossils, and the fossils refer them to the Caradoc age. The Caradoc rocks in the north-west of England are therefore referable to three groups, namely, a lower group consisting of ash-beds and porphyries, a middle series made up of limestones with shales (Coniston limestones), and an upper group composed of grey, flaggy, and gritty rocks (the Coniston flags and grits). In the Lake district there are no equivalents of the Middle Silurians, the Llandovery group, as no traces have been detected of the smooth *Pentameri*, of *Atrypa hemispherica*, or of any other characteristic fossils of this portion of the Silurian system. The rocks in the neighbourhood of Kendal, from the nature of their fossil contents, are distinctly of the Ludlow age, and it does not appear that in the Lake country any portion of the Silurians are exhibited which lie between the Caradoc sandstones and the Ludlow group.

Besides the north-east and south-west faults before alluded to, and which are of an ancient date, as they not only do not affect the Upper Old Red Sandstones and the overlying Carboniferous rocks, but have had the irregularities resulting from them planed down before the deposition of the Old Red Sandstones, there is another series of faults of a later date, which affects the Upper Palæozoic rocks. Along the lines of these newer faults, which have nearly a north and south direction, the most important of the Lakes occur. They give rise to the prominent north and south valleys, and in combination with the older system of faults, they produce in a great measure that bold and varied outline which gives so much beauty to this portion of the north-west of England.

On the Silurian Rocks of the Isle of Man.

By Prof. HARKNESS, F.R.S., F.G.S., and H. NICHOLSON.

The largest portion of the Isle of Man is occupied by rocks which have hitherto been regarded as appertaining to the metamorphic group.

These so-called metamorphic rocks form the cliffs and bold coast on the north-west and south-east sides of the island, and in the interior the mountainous portion of the country is composed of them. Exposures of these rocks are well seen on the coasts, but in the mountainous districts soil and peat to a great extent cover up the rocky masses.

The old rocks of the Isle of Man are not, however, of a metamorphic nature, but consist of dark grey slaty beds, which in some localities assume a coarser nature, and sometimes put on the aspect of quartz rocks.

These rocks, as they are seen in the neighbourhood of Douglas, dip south-east, and this dip continues, with some local variations, as seen along the coast, to Moar Creek on the south side of Maughold Head. On the north-west side of Moar Creek directly opposite dips occur, namely, towards the north-west, and in this locality the prominent axis which intersects the older rocks of the Isle of Man, and which has a north-east and south-west course, is seen. On or near the line of this axis, near Maughold Head, veins of hæmatite occur, which appear to have a direction corresponding with that of the axis.

The anticlinal axis can be seen on the opposite or south-west side of the island at Port Erin, to the north of which, along the coast, north-west dips prevail, until the older rocks are seen passing under the Old Red Conglomerates in the neighbourhood of Peel. South of Port Erin the inclination is towards the south-east, and this inclination obtains, with local exceptions, where the older rocks occur, along the coast to Douglas Bay.

There are two localities in the Isle of Man where the dark grey slates exhibit strata of a different nature upon them. These are Douglas Head and Bank How. The rocks here have a green colour, are distinctly bedded, and, at Bank How, have porphyries overlying them. These green rocks are conformable upon the dark grey slates. Their line of strike connects those seen at Bank How with those of Douglas Head; and between these two headlands, which form the north-east and south-west boundaries of Douglas Bay, the same rocks are seen forming the reef known as the Conistor rocks, upon which the Tower of Refuge is built.

There are no other rocks in the Isle of Man of an age intermediate between these green rocks and the Old Red Sandstone.

The dark grey slates and the green rocks, both in mineral character and arrangement, represent the Skiddaw slates and the succeeding green slates of the Lake country, and an extension of the strike from the Skiddaw country would place the old rocks of the Isle of Man also in the same line. These old rocks of the Isle of Man must therefore be considered as belonging to the Lower Silurian group.

On the Metamorphic Rocks and Serpentine Marbles of Connemara and Joyce's Country. By Prof. HARKNESS, F.R.S., F.G.S.

These rocks, forming a portion of the south-west of Ireland, have on their south side the granitic area of Galway, on the north of which an extensive development of gneissic rocks occurs. These gneissic strata have an east and west strike, and, although greatly contorted, have a prevailing south dip. Coming out from beneath them *conformably*, is a band of limestone, greyish in colour, and subcrystalline in nature. This limestone, in some localities, is highly serpentinous, and yields the green marble of Connemara. This green marble is most abundant where the limestone is highly inclined and greatly contorted. The limestone *reposes conformably* upon quartz rocks, the latter giving rise to the bold scenery of Connemara. The mode of arrangement of the metamorphic rocks in this portion of Ireland corresponds with that of the Highlands of Scotland; and these metamorphic rocks of Ireland are the equivalents of the upper quartz rocks, upper limestones, and upper or flaggy gneiss of Sir R. Murchison, being members of the Lower Silurian group.

It has been stated that the Connemara marble affords *Eozoon Canadense*, a reputed organism of the Laurentian rocks of Canada.

The structure in the serpentinous limestone which has given rise to this statement, the author believed to be of a purely mineral nature, resulting from asbestos and tremolite which have formed in cavities as crystalline skeletons upon which serpentine has been subsequently deposited.

On the Pre-Cambrian Rocks of Central England.

By HARVEY B. HOLL, M.D., F.G.S.

In this communication the author discussed the age of the crystalline rocks which form the narrow ridge of the Malverns, as also those smaller protrusions which pierce the Cambrian rocks and Keuper marl of Charnwood Forest. In their profoundly altered aspect, in the abundance of triclinic felspar, in the prevalence of hornblende as one of their ingredients, and in their general deficiency in free silica, the rocks in both these localities, though separated by a distance of 60 miles, have nevertheless a character in common. In the Malvern district they extend for about 8 miles due N. and S., and are again exposed further to the north, near Martley, making altogether nearly 16 miles for the entire length of the known area occupied by these rocks, but nowhere does it exceed $\frac{3}{4}$ of a mile in width. The dominant trend of the bedding is from S.E. to N.W., *i.e.* obliquely across the ridge; hence we learn that the area which these rocks occupy is only an uncovered portion of a much larger one, and it is not possible, therefore, to form an estimate of their thickness, beyond the general one that it is very great. As far as they are exposed, they consist for the most part of alternative belts of micaceous and hornblendic gneiss and schist, the foliation of which corresponds with the plane of the bedding. With these are interstratified belts of coarse, rudely-bedded granite, and of various granitoid and gneissoid rocks, especially towards the northern extremity of the range, with much coarse-grained diorite, and some subordinate beds of crypto-crystalline rock, which have no very definite character. These rocks are traversed by numerous quartz-felspathic veins, and by trap-dykes (diabase) of later date*.

In the Charnwood Forest district the rock is more massive, and the bedding for the most part effaced. At Mount Sorel the rock is entirely granite, and is composed of dark-coloured, ferro-aluminous mica, and a pale pinkish, subtranslucent, triclinic

* For a fuller description of these rocks, see the author's paper "On the Geological Structure of the Malvern Hills and adjacent district," in Quart. Journ. Geol. Soc. for Feb 1865.

felspar, with a variable proportion of quartz; and is remarkable, inasmuch as it includes masses varying in size from a walnut upwards, of a finer-grained and otherwise dissimilar rock. In the great quarries near the village of Mount Sorel it is impossible to distinguish satisfactorily the bedding from the jointage, but south of Quorndon an east and west strike is observable. As in the Malverns, the rock is traversed by trap-dykes, one of which may be seen near the Windmill, and another in a quarry on the road which skirts Baddon Wood. At Kinchley Hill the rock contains hornblende as well as mica, and proceeding southward, at Bazil Wood, some large-grained diorite is seen associated with granite, both coarse and fine-grained, which latter is succeeded by purplish-brown, highly micaceous, crumpled schist and gneissic rocks, having an east and west strike.

Other protrusions of these crystalline rocks occur in the neighbourhood of Newtown Linford, Grooby, Markfield, Hammercliff Hill, &c. In these knolls the rock contains hornblende in place of mica. The felspar is partly of a pale greenish colour, and uncleavable, and partly triclinic, having the same pinkish, subtranslucent appearance as that of the granite of Mount Sorel. Quartz is either absent altogether, or occurs in small proportion only, and occasionally, as near Grooby, the rock contains epidote. Although similar in mineral composition, these rocks vary slightly in their general appearance, according to texture and to the relative proportions of their hornblende and green felspar, forming parallel belts or beds of rock of somewhat dissimilar aspect, which on the north and west of Grooby may be seen to trend from W.N.W. and E.S.E. to N.N.W. and S.S.E.; but further westward, as at Markfield and Cliff Hill, the rock is more uniform in structure, and the direction of the strike cannot be determined satisfactorily. At Hammercliff Hill part of the rock is dark-coloured, from the abundance of hornblende it contains.

The Lower Cambrian rocks, through which these knolls protrude, have been upraised along an anticlinal axis, which extends N.N.W. and S.S.E. from Whitehorse Wood to Holgate Lodge. From this line the rocks dip away to the N.E. and S.W., at angles varying from 30 to 60 degrees; but from this general direction of the dip there are many local deviations. In appearance they resemble precisely the Lower Cambrian rocks of Wales, and consist of purplish, blue, and green slates, with grits and conglomerates, and interstratified beds of volcanic porphyry and ash. These latter are well seen in the high ground which extends from Hobs Hole to Green Hill, at Bardon Hill, Birch Wood Hill, and along the ridge which stretches N.N.W. from Bradgate Park. Encircling this small area of exposed Lower Cambrian rocks are the Keuper marls, which rest on them horizontally, except on the north, where the underlying sandstone (Water-stones) intervene the marl and the Cambrian rocks; and, as observed by Mr. Howell, "it is worthy of notice that the marl contains fragments and boulders of the older rocks where in contact with them"*.

In the Malvern district the oldest overlying rocks are referable to the age of the Middle Lingula flags, which rest unconformably on the gneissic rocks of the hills; and in the shallow-water conditions under which their lowest beds were accumulated, and in the successive overlap of the succeeding ones, we learn that the metamorphic rocks formed land in the Lower Cambrian sea, and that an interval of unrepresented time preceded the deposition of the Malvern Lingula flags†.

Now, with respect to the age of these quasi-syenitic and granitic rocks of Charnwood Forest and its vicinity, their massive and highly crystalline condition might countenance the view that they had had an igneous origin, although they show, here and there, undoubted traces of stratification, without any change in mineral character; but assuming for the moment that they have had this origin, there is a total absence of any evidence of heat-action upon the contiguous Lower Cambrian rocks, and we may therefore conclude that the latter had no existence at the time of their eruption. On the other hand, regarding them as metamorphic, their mode of occurrence with respect to the Cambrian rocks, and the circumstance that some of the grits contained in the latter, as, for instance, that near the windmill north of Markfield, are made up of rounded grains of felspar, hornblende, and quartz, tends equally to show that they existed before the era of the Lower Cambrian rocks.

* Memoirs of Geological Survey. Explanation to Horizontal Section, Sheet 48.

† See further, the paper already quoted in Quart. Journ. Geol. Soc. vol. xxi. part 1.

That the age of the metamorphic rocks of the Malverns is earlier than that of the Hollybush Sandstone (Middle Lingula-flags) is clear, inasmuch as the latter rests unconformably on their upturned edges. How much older may be inferred from the fact that between the period of the accumulation of the sediments from which these metamorphic rocks were derived, and that of the overlying sandstone, there took place all those changes which gave to these sediments their crystalline structure, and which involve the lapse of a long interval of time; for profound metamorphism of rocks over a large area is never solely due to the intrusion of erupted masses, but is always the result of a widespread and general cause, *i. e.*, the broad depression of the area to within the influence of the earth's internal heat; and in this change of level and subsequent relevation of the area and uptilting of the rocks into highly inclined positions, and in their still later invasion by trap-dykes (all of which events were fulfilled prior to the period of the Hollybush Sandstone), we have a measure, as it were, of the length of this interval.

It is highly probable that the intrusion of some of the associated igneous rocks, as, for instance, the diorite, and possibly some of the granite, may have been contemporaneous with the metamorphic action; having taken place into fissures and chasms in the crust while depressed and still in a heated state, judging from their coarsely crystalline condition at their line of contact with the metamorphic rocks, and especially in the small granitic and other veins*. But as regards the trap-dykes, both in the Malvern district and at Mount Sorel, they were evidently of later date, as shown not only by their mode of occurrence, but by their amorphous or minutely crystalline condition at their margins and in their offsets, consequent upon their having come into contact with rocks in a cool state, and capable of *rapidly* abstracting their "heat of fluidity."

Whether or not certain associated granitic rocks be metamorphic or igneous, is not now, however, a question for consideration, as in either case they are equally pre-Cambrian in age.

As already stated, the metamorphic rocks of the Malverns were upraised prior to the era of the Hollybush Sandstone. They constituted in fact a mountain-range, the crest of a slowly subsiding area of emerged land, during the period in which the Lower Cambrian rocks of Charnwood Forest and the Longmynd were being deposited, and as this subsidence went on, higher beds were brought consecutively into direct contact with the metamorphic rocks, until finally, at the close of the Lingula-flag epoch, the area may have been nearly or entirely submerged and covered up. There thus occurred a blank in the sequence of sedimentary deposits, the result of the reverse of that change of level which gave rise to metamorphism, and which attends the accumulation of sediments, *viz.*, a local elevation of the crust, and emergence of the area from which the next overlying formation is absent. As these blanks or gaps belong to all ages, it follows there must always have been areas of dry land; and as the mean sea-level, and therefore the relative proportions of dry land and water, probably never varied very greatly, there must have been emerged land in Lower Cambrian times over areas equal to at least a fifth of the earth's surface, on which no deposition was taking place, forming breaks in the sequence of formations to which pre-Cambrian rocks formed the floors. From this emerged land were derived the sediments that accumulated in the Cambrian seas. The absence of the Lower Cambrian rocks from the Malvern district, therefore, has no greater significance than the absence of the Carboniferous limestone from beneath the Coal-measures of Bewdley or of Newent, or of the Old Red Sandstone from the area of North Wales.

But at some time after the close of the Lingula-flag period, and between it and the epoch of the May Hill Sandstone, the Malvern area was again elevated, as may be inferred from the total absence of the Llandeilo, Caradoc, and Lower Llandovery rocks, and from the tilted position of the Lingula beds, on the denuded surfaces of which the May Hill Sandstone rests, dipping to the westward at a lower angle than the beds which underlie it. Again, at the close of the Lower Old Red Sandstone period, the ridge was upraised, as seen in the absence of the Middle Old Red Sand-

* It is equally probable, however, with respect to the diorite, that its coarsely crystalline structure may be due to the action of heat on rocks having the same composition that pre-existed the metamorphism of the area, *ex. gr.*, traps and some lava beds.

stone (*Glyptolepis* beds of Scotland), from the adjacent district, and in the attenuation of the Upper Old Red (Devonian beds), the Carboniferous limestone and Millstone-grit in the direction of the Malverns. And lastly, in the unconformable position of the Coal-measures, both on the north and south of the range, and of the Permian breccia to both the Coal-measures and overlying Trias, we have further evidence of repeated oscillations of level.

Similar changes of level affected the Cambrian area of Charnwood Forest. The Upper Cambrian and the whole of the Silurian and Old Red Sandstone systems are entirely absent. It was dry land in early Carboniferous times, as pointed out by Professor Jukes. It was subsiding, however, throughout the latter part of that epoch, and continued to do so until the close of the era of the lower Coal-measures. The upper Coal-measures are not known to occur in the neighbourhood with certainty, at least the evidence of their presence is not conclusive, and the Permian system not nearer than Ashby-de-la-Zouch, where some "meagre traces" are supposed by Mr. Hull* to occur, forming marginal outliers of the formation. Be this as it may, the area was certainly upraised, and was probably dry land in the early Triassic sea, as shown by the shallow-water conditions which prevailed at the commencement of that period, and by the gradual subsidence of the area which followed during which the Keuper marls closed over it.

Remarks on the Geology of Parts of the Sinaitic Peninsula.

By the Rev. W. HOLLAND.

The peninsula is composed of three geological elements. The first and most extensive is the northern table-land of limestone, the Desert of the Tih. The next, the sandstone formation—the great mining district of the Egyptians. The third, the granite formation, which included the greater part of the south of the Peninsula. Further, the raised beaches, especially on the western side, are of great interest. The author had obtained specimens of existing shells to the north of Tor, at a height of 20 to 30 feet above the present level of the sea, and large blocks of coral occurred at a still greater elevation. He had also shells from the old bed of the Gulf of Suez, a few miles south of the ruins of Serapeon. In following the proposed line of the maritime canal from Lake Tinsall to Suez, he found the desert quite white in many places with beds of shells, and in one part for nearly four hours he was walking across a bed of solid rock-salt, about 4 feet in thickness.

Fossil Footprints in the New Red Sandstone at Brewood, near Wolverhampton.

By the Rev. H. HOUSMAN.

Notice of the Occurrence of certain Fossil Shells in the Sea-bed adjoining the Channel Islands. By J. GWYN JEFFREYS, F.R.S.

In the course of his dredging explorations this year among the Channel Isles, Mr. Jeffreys found shells of species, some of which are extinct, and one is not known to inhabit at present the North Atlantic. They were taken with living mollusca, at depths varying from 12 to 20 fathoms, and in different parts of the sea-bed. The specimens in question had the same appearance as dead shells of recent species; one of them was in a most perfect state of preservation, and evidently had not been rolled or transported to any distance from its original place of habitation. They consisted of *Potamides tricarinatus*, Lam., and *P. cinctus*, Lam. (both Eocene fossils), a species of *Terebratula* (or *Terebratulina*), which Mr. Davidson referred with doubt to *T. squamulosa* of Baudon (from the Calcaire Grossier), and *Rotalia (Discorbina) Trochidiformis* of Lamarck, also an Eocene fossil, but larger than specimens from the Bracklesham beds. No tertiary deposit has been noticed in any part of the Channel Isles; but the discovery of the above-mentioned fossils in the adjoining sea-bed, occupying an intermediate position, would seem to connect this district with Hampshire and Normandy, and to show the great extent of the Eocene basin or area which formerly existed. Another species obtained by the same dredgings, near Jersey, was *Cerithium vulgatum*,

* Geology of Leicestershire Coal-Field, p. 57.

Bruguère. Several specimens were found, one in a tolerably fresh condition. This species inhabits the Mediterranean and Adriatic, throughout many parts of which it is most abundant. It does not appear that living specimens have ever been found elsewhere, although Lamarck gave the North Atlantic as a locality. M. Cailliaud, of Nantes, included *C. vulgatum* in his list of Mollusca from the Département of Loire-Inférieure, having frequently met with shells thrown up on the beach; and Professor Sars recorded the discovery of a specimen inside a codfish caught off Bergen. Mr. Jeffreys believed that *C. vulgatum*, which usually inhabits large estuaries and salt marshes, once lived in such situations between Jersey and the mouth of the Loire, and that this tract has since been submerged, and consequently become unsuitable for the continued habitability of the *Cerithium*. The presence of submarine peat near the Channel Isles and in the Bay of Mont St. Michel, tends to confirm the supposition; although it is by no means certain that the submergence has occurred within the historical period, as suggested by the Abbé Manet, Mr. Peacock, and others*.

The Extent and Duration of the South Staffordshire Coal-field.

By H. JOHNSON.

Both the extension and duration of this coal-field are questions open to a very great difference of opinion; and it is to the confines of the present coal-field that any hopes for fresh supplies can be looked for. On all sides of the coal-field explorations are being successfully carried on, with perhaps the exception of the eastern boundary on the Birmingham side; but the great depth at which the thick coal has been last worked in the neighbourhood of West Bromwich (about 400 yards) has probably retarded explorations. The result of operations going on in other portions of the field is looked forward to with great interest, as affording a warrant for an attempt to reach the coal through the Permians at Smethwick and Harborne. During the last ten years, a great number of new winnings have been made in the Cannock Chase district, at Aldridge, Himley, and other places; but the most important recent trial sinkings are those on the south end of the coal-field, in the neighbourhood of Hales Owen, Congreaves, Cradley Park, and Wassel Grove. In the event of those at Hales Owen and Wassel Grove discovering the thick coal—both looking promising, and now sunk about halfway—more than 4000 acres of the thick seam may be considered proved, and this assurance will, no doubt, give a fresh impetus to additional search further south. A scheme for proving the continuity of the coal-field underneath the Permian on the down-throw side of the Great Western boundary-fault at Essington is now in course of formation. It is proposed to form a fund, by subscription, from all the adjoining landowners likely to be benefited. It is proposed to drive from the existing workings on the upthrow side, at a depth of about 200 yards, across the fault into the Permian district, and then to bore up or down to discover the position of the coal-measures underneath. There is, however, a more comprehensive scheme for exploring the whole Permian districts lying between the South Staffordshire coal-field and the Warwickshire and Shropshire coal-fields. To attempt to estimate the probable duration of the coal-field whilst these important additions are being added, would be impossible; but it may be observed that such additions are not keeping pace with the enormous consumption and consequent rapid destruction of the parent portion of the coal-field. In a valuable paper by Mr. Matthews in 1860, he estimated the then duration of all parts of the coal-field at an average of about forty years. There can be no doubt but that in one-half that number of years a very large portion of the earlier-developed part of the coal-field will be totally and for ever exhausted.

On the Silurian Rocks and Fossils of Dudley. By C. KETLEY.

This paper has special reference to the proper classification of the bed of shale which immediately overlies the Wenlock limestone of Dudley, and which has

* Fossil shells procured by Mr. Jeffreys in his Shetland dredgings were of Arctic and high northern species; those now obtained were tropical or southern.

yielded some of the most interesting and beautiful of the organic remains of the Upper Silurian rocks.

Its relative position may be seen by reference to the Geological Survey, Horizontal Sections, sheet 24, section 2.

There is no good natural section of it, but it has been exposed at several places by sinkings and excavations, and is now seen in a cutting at the Dudley Railway Station. In the same cutting, near the Trindle, there formerly existed a section showing the coal-measures resting on the shale, and showing also a cliff in the shale, but that section has been obscured or destroyed; it is, however, well-figured in Prof. Jukes's 'South Staffordshire Coal-field.'

By some authorities this shale is classed as Ludlow, by others as Wenlock.

Sir R. I. Murchison in 'Siluria,' Mr. Salter in his 'British Trilobites,' and the Dudley Geological Society, in their Reports, have placed it in the Ludlow series.

Prof. Jukes, in his 'South Staffordshire Coal-field,' mentions it as belonging to the Ludlow, but in another part of the same work shows it to belong to the Wenlock.

The Geological Survey Map and Sections have it coloured as Wenlock shale, excepting a recent edition, in which it is coloured as Lower Ludlow.

In the Jermyn Street Catalogue, lately published, the localities of the Silurian fossils from the Dudley rocks, including those from the shale in question, are given as Wenlock. And Prof. Morris, in his 'List,' published in the first volume of the 'Geologist,' gives the "localities and fossils of the Lower Ludlow," but does not include Dudley or the Dudley shale in his "localities," nor the characteristic species of this shale in his "fossils." Of its many Trilobites, not one is shown.

In 'Siluria' it is stated that "from the physical relations of this shale, and from its forming usually a part of the same hills as the mass of the Ludlow rocks, it is classed with that formation; though in reality it is only an intermediate band intimately uniting the Wenlock and Ludlow, and is almost equally connected with both by structure and fossil contents."

As to fossil contents, the materials for examination have greatly increased since the passage in 'Siluria,' above quoted, was written. The fossils from the Upper Shale then available would be derived principally from one locality only, and consisted, for the most part, of species of the classes Lamellibranchiata and Cephalopoda, in which the Ludlow rocks are so prolific, but of which many are found also in the Wenlock limestone. Besides these, however, this shale, examined in other places, is found to contain most of the Zoophyta, Crustacea, Bryozoa, Brachiopoda, and Gasteropoda, all so common in the Wenlock limestone below it, but so meagrely represented in the typical Lower Ludlow rocks of the Ludlow district.

In illustration of this, lists of the principal fossils are appended; a summary of which shows that of CORALS this Upper Shale has twenty seven species, of which twenty-three are found in the limestone below; but none of them are found in the typical Lower Ludlow rocks of the Ludlow district.

Of TRILOBITES, the Upper Shale has twenty species and subspecies, fourteen of which are also in the limestone below. The Lower Ludlow of Ludlow district has eight species, four of which are also in the Upper Shale and the Wenlock limestone; and of the remaining species, three are in the Upper Shale, but not in the limestone.

Of the BRACHIOPODA, the Upper Shale has twenty-nine species, twenty-four of which are also found in the limestone below. The Lower Ludlow of Ludlow has ten species, of which six are common to the limestone, Upper Shale, and Lower Ludlow, and two of them to the Upper Shale.

Does it not thus appear that the fauna of this shale has, on the whole, a closer relationship to that of the Wenlock limestone below it, than to that of the Ludlow rocks above?

The highest authorities—both Sir R. Murchison and Prof. Jukes—consider this shale to be lithologically undistinguishable from that below the limestone.

And while it overlies, and is conformable to the Wenlock limestone, it is not found to have any of the Ludlow beds deposited upon it. This is clearly shown in Jukes's 'South Staffordshire Coal-field,' thus:—"The uppermost member of

the Silurian formation, the Ludlow group, is only found on the western side of the main part of the coal-field. If we draw a nearly north and south line, starting from Ettingshall Park Farm, running between Hurst Hill and Sedgley Beacon, and continue it down through Cradley to the south, we find that to the west of that line, wherever the Silurian rocks rise to the surface, namely, at Sedgley, at Turner's Hill, and at the Lye Waste, they consist of the Ludlow or upper division, while all to the east of that line, wherever the Silurian rocks rise to the surface, or have been reached by shafts through the coal-measures, they consist of the Dudley and Wenlock division."

All the localities of this shale are east of this line, and accordingly it belongs to the Wenlock series.

Annelida from Guernsey.

By E. RAY LANKESTER, *Scholar of Downing College, Cambridge.*

This paper contained an account of the Annelids and Turbellarians obtained by the Dredging Committee in Guernsey. The author had been able to distinguish seventy-seven species from this coast, of which four at least, belonging to the *Polynoïna*, were new to science; others not previously obtained from British localities were also in the list of the new species; one, a *Halosydna*, the author named after Mr. Jeffreys, the other forms were also named and characterized; *Harmothoe Sarniensis* was remarkable for its unusual development of elytra, which were twenty pairs in number.

On the British Species of Cephalaspis and the Scotch Pteraspis.

By E. RAY LANKESTER.

The author stated that he had acquired a very large mass of evidence by the assistance of various friends, particularly Mr. Powrie, of Roswallie, Forfar. From these specimens he concluded that there were at least five British species of *Cephalaspis*; and they were—*C. Lyellii* of Agassiz, confined to the Scotch beds (which are very low), and perhaps occurring also in the passage-beds of Herefordshire, as *C. ornatus*, a form only known by fragments; *C. Murchisoni* of Egerton, from the passage-beds of England; *C. asterolepis* of Dr. Harley, a well-marked form found in the cornstones; *C. Salweyi* of Egerton, also well characterized; and lastly, the species common in the English cornstones, which appears to differ considerably from *C. Lyellii*, as the author showed. This species will be named, and other details given, in the monograph on these fishes in which Mr. Lankester is engaged in conjunction with Mr. Powrie.

The Relative Extent of Atmospheric and Oceanic Denudation, with a particular reference to certain Rocks and Valleys in Yorkshire and Derbyshire. By D. MACKINTOSH, F.G.S.

The object of the author was to show that most of the cliffs, projections, and pillars of rock hitherto attributed to *weathering*, are really due to the former action of the sea during the last great submergence of the land. Many of the escarpments or cliffs of Yorkshire and Derbyshire present evidences that they could only have been formed by the battering, undermining, and displacing agency of the sea. "The multitudes of scattered blocks and fragments frequently found lying under escarpments, do not in general present the appearance of their having fallen since the last emergence of the land. They exist in too great numbers, at too great a distance from the parent cliff, or arranged in such positions as to point to the peculiar action of the sea." The Brimham rocks, nine miles from Harrogate, "fringe an eminence which a geologist can scarcely err in regarding as an upheaved island, partly spared, and partly wrecked by the sea. . . . The shapes of most of the rocky pillars at Brimham must have originated in the jointed structure of the millstone-grit strata of which they are the remains. The passages between them have evidently been chiefly excavated by the displacement of blocks, and not so much by disintegration. Some of the rocks have been more or less smoothed and rounded; but a little practice will enable a geologist to distinguish between the effects of frost and rain, and the shapes communicated to rocks by waves, tides,

and currents. The stones from New Red Sandstone quarries, of which many old churches have been built, furnish a specimen of atmospheric effects, namely, a very irregular *pitting* or *roughening* of the surface, without any *special* or *determinate shape* being produced. . . . Some of the Brimham rocks furnish evidences of their having been shaped by a cause forcibly propelled in a particular direction, so as to wear away soft and hard parts alike. Many of them present forms which show that they have resisted atmospheric action since they rose above the sea. Numerous blocks may be seen with angles nearly as sharp as when they were originally displaced, and the sides of many pillars, passages, and crevices reveal the jointed surfaces of the rocks as fresh-looking as when the displacements and rents occurred. . . . At Brimham there are appearances which can only be explained by marine agency. First, a line of cliff extending along the western and north-western side of the eminence. A detached part of this coast-line, behind Mrs. Weatherhead's house, shows a projecting arched rock which a geologist familiar with sea-coast scenery could have no more hesitation in referring to oceanic action than if he beheld it still whitened by the spray. Further to the north, this line of cliff, in some places nearly 100 feet high, shows many of the more striking characteristics of a modern sea-coast. Here an immense block of millstone-grit has tumbled down through an undermining process,—there a block seems ready to fall, but in that perilous position it has probably remained since the close of the intraglacial or ice-floe period. On the top of this old sea-cliff, and extending for a considerable distance inland, may be seen the rocky pillars which form the main attraction of Brimham. They present resemblances to mushrooms, tables, anvils, and trees. Generally speaking, they are largest at the top, and smallest underneath. The *Idol Rock*, which is about 20 feet high, and upwards of 40 feet in circumference, rests on a pedestal varying from about 3 feet to little more than 18 inches in diameter. The undermined appearance presented by this and other rocks at Brimham, can only be explained by the laterally-operating agency of the ocean. . . . Rain, assisted by detached pebbles of quartz, may have excavated some of the rock-basins occurring on the upper surfaces of rocks. But at Brimham we find basin-shaped hollows underneath rocks (the double basin, with a supporting pillar, called the Kissing Chair, for instance) in situations to which the sea alone could have gained access. . . . The Rocking-stones at Brimham present every indication of their being nearly in their original positions. At one time they must have formed a continuation of the beds of millstone-grit, of which they are now only the remains. The adjacent blocks or particles would appear to have been carried or washed away, and the line of bedding between each rocking stone, and the block beneath, must have been widened by the insinuating and erosive action of the waves, so as to leave it with a sufficiently slender support to allow it to be easily set in motion." Mr. Hull, in the *Quart. Journ. of the Geol. Soc.* (Aug. 1864), has given an account of similar "sea-shore rocks" as occurring in "multitudinous assemblages" on the Peak Mountain in Derbyshire. To the observations of Mr. Hull I would add, that as these rocks are found at an elevation of about 2000 feet above the sea, and in the most exposed situation, no one can say that the atmosphere has not there had a fair chance of competing with the sea as a denuding agent. But it would appear that many of the monuments the sea left behind it thousands, if not hundreds of thousands of years ago, have ever since mocked the effects of rain and frost; and if the sea-shore rocks of Brimham, the Peak, and numerous other parts of England have retained their wave-worn shapes for so long a period, what is to hinder them, secure within their mossy armour, from continuing to resist the storm and the waterspout until the sea shall again claim these monuments as its own, and decompose them into the foundations of future continents.

The Red Sandstone of Nova Scotia. By the Rev. A. W. McKAY.

These are the newest rocks known within the colony, if we except the boulder-drift. They are limited in their range to the neighbourhood of the Bay of Fundy. The colony of Prince Edward Island consists wholly of them. Here they are thicker and more compact, and are extensively used for building purposes. In Nova Scotia this is never the case, on account of their softness and brittleness. They are found chiefly in the Valley of Kings and Annapolis counties, bounded

on one side by the range of high hills known as the North Mountain; and on the other by the northern termination of the hills of the Devonian series. They underlie one of the most fertile districts in the colony.

There are evidences in this locality of extensive denudation. The sandstone is found high up on the sides of the abrupt termination of the trap hills already referred to, and is mingled with the igneous rocks on the face of Cape Blomidon, far above the level of the surrounding country.

They have not been found in Nova Scotia to contain any fossil remains. In Prince Edward Island there have been obtained from them some specimens of fossil wood, and the jawbone, together with seven teeth, of a Saurian reptile, named by Dr. Leidy, of Philadelphia, *Bathynathus borealis*. These would appear to point to the Permian period of Europe as the probable time of its formation.

This is confirmed from another source. The trap associated with them was upheaved after the whole formation had been deposited. This trap seems to be of the same age as the trap of New Brunswick and that of the Alleghany Mountains in America, an extension of which runs eastward through Lower Canada as far as the Bay of Chaleur, where there is found associated with it red sandstone beds similar to those described above. The red sandstone of the Connecticut river-valley was deposited after the upheaval of the Alleghany Mountains, for it rests unconformably upon the upturned edges of carboniferous strata disturbed by the igneous outburst. It necessarily follows, therefore, that the red sandstone of the eastern provinces and those of Connecticut are of different ages, the former being earlier, and the latter later, than the trap hills and mountains referred to. The red sandstone of Nova Scotia was first deposited, then followed the trap upheaval, and when the disturbance had subsided, the red sandstone beds of Connecticut were laid down.

The colour of these beds seems to be derived from the iron contained in the neighbouring metamorphic rocks. It occurs in these latter in three different forms. 1. There is a quantity of it distributed generally throughout the slate and shale, of which these strata are composed; 2. there are veins and beds of specular iron ore, as in the Devonian rocks of Nictaux; and 3. it occurs in the shape of bisulphide of iron or iron pyrites. When these metamorphic rocks were worn away, the iron set free was oxidized by contact with the atmosphere, and mixed up with sediment as it was laid down.

On some Fossiliferous Strata occurring between the Bunter Sandstone and Mountain Limestone of the Vale of Clwyd, North Wales. By GEORGE MAW, F.S.A., F.G.S. & F.L.S.

The Ordnance Geological Survey map places the Bunter sandstone, occupying the vale of Clwyd throughout its boundary, either adjacent to the mountain limestone, or to the Denbighshire shales and grits. In several places along its eastern side strata intervene, consisting of mottled sandstones, variegated shaly marls, containing plant remains and dark micaceous sandstones. The marly shales abound with plant impressions, which Mr. Etheridge, palæontologist to the Survey, considers to be of a Permian type, and unlike carboniferous forms. These beds are for the most part conformable to the mountain limestone, dipping unconformably under the brick-red Bunter sandstone towards the vale of Clwyd. In lithological aspect they strongly resemble Permian strata. The principal localities where they are exposed are at Pentre celyn, near Llanfair, in the wood above Llandibr Farm, and in a lane between Llandibr Farm and Llangynhafal. Red and variegated marls and marly shales, containing some soft coal, and resting on the mountain limestone, occur also at Rhiwbibill near Llangwyfen, opposite Denbigh. Although apparently conformable to the carboniferous limestone, it is probable that they rest on its eroded surface.

The millstone-grit is developed in great massiveness within four and a half miles to the east of Pentre celyn, and a small outlier crops up in the Vale of Clwyd at Ty Côch, a mile and a half to the north. Its absence at Pentre celyn could not be accounted for from the thinning out of its mass within so short a distance, or excepting from erosion: if a break really occurs, the marls and shales resting on the limestone could not be of carboniferous age.

On an Extensive Distribution of White Sands and Clays in North Wales antecedent to the Boulder Clay Drift. By GEORGE MAW, F.S.A., F.G.S. & F.L.S., Vice-President of the Severn Valley Field Club.

There exists in the counties of Carnarvon, Denbigh, and Flint, a widely distributed series of unfossiliferous deposits older than the Boulder-clay on the evidence of superposition, and differing from it in lithological character, but closely resembling some of the Tertiary deposits in the south of England.

They consist for the most part of white, black, and yellow sands, interstratified with tough, white and grey pipeclays and earthy lignite, generally occurring in pockets or egg-cup shaped depressions in the mountain limestone at altitudes of from 800 to 1000 feet above the sea, but not exclusively confined to the limestone.

Among the localities are Gwydfyd, on the Great Ormes Head, Nant y Gamer at the back of the Little Ormes Head, several places on Halkin Mountains, near Holywell, at Pant du and other localities in the neighbourhood of Mold in Flintshire,—all on the mountain limestone. Also a deposit of similar white sand and clay rests on Lower Silurian rocks at the back of Conway mountain, Carnarvonshire. The strata are generally broken and dislocated, with a frequent tendency to a vertical arrangement, or a concave bending of the beds into the form of the cavities in which they are contained.

A theory is referred to which has been advanced by Mr. Prestwich and others to account for analogous phenomena exhibited in the excavation of sand-pipes and pockets in various calcareous formations as applicable to the formation of the Welsh deposits, viz., that the cavities were formed subsequently to the beds that now occupy them, and that, as the pockets were slowly excavated by watery dissolution, the preexisting superincumbent beds were gradually lowered into them.

Tufa deposits frequently accompany sand-pipes in calcareous formations, and are supposed to result from the redeposition of calcareous matter dissolved away in their excavation.

In the valley below Caerwys a great deposit of about 200 acres of tufa exists, resting on boulder-clay drift, and as it was adjacent to a cavernous opening in the limestone escarpment, it is probably connected with the subterranean dissolution of the limestone and of the excavation of the pockets in the adjacent mountain limestone range. The order of geological events these phenomena imply may be generalized as follows:—

1st. The deposition of the white clay and sand strata at some time since the principal erosion of the mountain limestone, which took place about the Permian period.

2nd. The partial excavation of the pockets, and the gradual lowering into them of portions of the previously existing deposits.

3rd. The erosion of the great mass of the formation not protected in the pockets, and the deposition of the boulder-clay drift.

4th. The continued excavation and deepening of the limestone cavities after the boulder-clay period, accompanied by the redepositing of the calcareous matter, carried away in watery solution, as tufa.

Deposits of a similar character occur in the mountain-limestone district of Tipperary.

On hitherto unrecorded Leaf Forms, &c., from Alum Bay, Isle of Wight.
By W. S. MITCHELL.

On the Coal-Measures in Mold Valley, and their Products. By W. NESS.

On Steam as the active Agent in Earthquakes. By R. A. PEACOCK, Jersey.

The author had collected seventy evidences of the presence of steam or its constituents in every species of natural disturbance of the earth's crust. It was proved by investigation of series *z* of M. Regnault's most excellent experiments *, that in saturated steam of the temperatures $241\frac{1}{2}^{\circ}$ to 447° F., the pressure increased in the

* Mémoires de l'Institut, vol. xxi.

enormously rapid ratio as the $4\frac{1}{2}$ power of the temperature, very nearly. The pressure with the latter temperature, viz. 409 lbs. to the square inch, is the highest limit of present exact knowledge. What the pressure is at the greatest temperatures attainable we do not know, but we have some indications that at a high temperature it is very great indeed. The Rev. John Michell * states that in casting two brass cannons, "The heat of the metal of the first gun drove so much damp into the mould of the second, which was near it, that as soon as the metal was let into it, it blew up with the greatest violence, tearing up the ground some feet deep, breaking down the furnace, untiling the house, killing many spectators on the spot with the streams of melted metal, and scalding many others in the most miserable manner." These great effects were evidently all produced by the steam of a few ounces of water only, for it is called merely "damp." It must therefore have been very powerful steam. Now the temperature of melted brass is known to be only 1869° F., which would be reduced by absorption of latent heat, and by raising the temperature of the damp, and the mould, and the neighbouring sand. But the heat of melted stone or lava is 3000° F., or, according to some, 3200° F. And since the Gulf of Santorin in the Grecian Archipelago has been for 2000 years a scene of volcanic operations†, it appears the mass of fire below is so very vast that the sea has not been able to quench it, and therefore the heat of the steam will closely approach to 3000° or 3200° ; for the water scarcely reduces even the surface temperature of so prodigious a mass; radiation instantly replaces the heat abstracted, by other heat. Since, therefore, saturated steam or its constituents is so very often present in all species of natural disturbances of the earth's crust, it is worth while to remember, on the bare chance of the pressure continuing to increase as the $4\frac{1}{2}$ power of the temperature, that in that case saturated steam of the highest temperature would have a force of at least a thousand tons per square inch, which would be amply sufficient to cause the greatest effects of earthquakes and volcanos. M. Regnault says (p. 619) that the graphic curve by which he represents his pressures and temperatures "*présente un point d'inflexion*" at $627^{\circ}\cdot2$ C. = $1160^{\circ}\cdot96$ F.‡ "*Enfin,*" says he, "*la courbe, qui tournait sa convexité vers l'axe des températures,*" up to the temperature named, "*tourne sa concavité vers ce même axe, à partir du point d'inflexion, l'ordonnée tend vers un maximum, et la courbe a pour asymptote, une ligne parallèle à l'axe des températures, dont l'ordonnée est. . . 121617 atmosphères,*" which are equal to about 800 tons per square inch. "*Ce serait donc là la limite supérieure de la force élastique de la vapeur.*" As far as he can judge. But he very properly adds, "*Mais il serait à mon avis tout à fait déraisonnable d'attacher une signification réelle à ces points singuliers de la courbe, qui sont si loin en dehors des limites où nos observations peuvent atteindre.*" Supposing he is correct in saying that steam pressure may continue to increase up to about 800 tons per square inch and *no higher*, that force would still account for the greatest effects of earthquakes and volcanos.

The volume of steam compared to the volume of water which produced it when the pressure is $26\frac{1}{2}$ lbs. to the square inch, is known to be about 941 times as great, whilst, when the pressure is 60·6 lbs., the volume of steam is known to be only about 432 times as great as that of the original water§. And the author of the paper thought that heat compresses steam in the same way, though not in the same degree, as the force-pump compresses water in the hydrostatic press; and that supposing the strength of the containing vessel unlimited, and the supply of water sufficient to saturate the steam, the force or pressure attainable would only be limited by the *maximum* heat in one case, and the *maximum* pumping power in the other; and the conclusion he arrived at was, that steam certainly operates *quantum valeat* in producing earthquakes, volcanos, and other similar disturbances; and that other forces cooperate, where no help is required.

He classified the seventy evidences from Humboldt, Lyell, and other authorities under the following heads:—1. The contact of the metalloïd bases with water and air may be a cooperating cause in volcanic processes. 2. Ejections of steam from

* Phil. Trans. Roy. Soc., 1760, vol. xi. p. 458.

† Lyell's 'Principles of Geology,' 1853, p. 441.

‡ 1141° is the heat of a common fire.—*Daniell*.

§ Useful Information for Engineers, second series, by Dr. Fairbairn, LL.D., F.R.S., p. 313.

volcanos. 3. Ejections of steam from earthquakes. 4. Ejections of steam from geysers. 5. Rocks ejected from a volcano by steam. 6. Active volcanos below the sea necessarily produce steam and earthquakes. 7. Ejections of water and of mud (which implies the presence of water) from volcanos; also sinkings of rivers and other waters. 8. Ejections of water, often hot, from earthquakes; from risings and sinkings of strata; and from earthquakes combined with volcanos. 9. Earthquakes fed by water. 10. Active volcanos fed by water. 11. Volcanos, earthquakes, hot water, and increasing temperature of hot springs; sometimes all connected together. 12. Deposits of water, and of ice and snow, ready to descend into volcanos by gravitation. The evidences appear in detail in the 'Artisan' of January, February, and March 1866.

On Extensive and Deep Sinkings of Lands in the Channel Islands Seas, and on some Changes of the French Coast of the Bay of Biscay within the Historical Period. By R. A. PEACOCK, Jersey.

It is well known that quantities of trees with roots attached, and other supramarine products, have been found all along the west coast of Normandy, along the eastern half of the north coast of Brittany, in the Bay of Mont S. Michel, on the west, south, and north-east of Jersey, and on the east and west of Guernsey, between high and low water, and even lower than the latter. Not only so, but in 1787 thousands of trunks (with roots) of trees were washed up on the west of Jersey from Rigdon shoal and Great Bank, which are respectively at 2 and 3 miles westward of high water, and on the latter of which banks the soundings are from 7 to 9 fathoms at low water, and the greatest rise of tide 42 feet. And supposing the original height of the ground 10 feet above high water, it follows there must have been a sinking of at least a hundred feet. Prodigious quantities of trees also came up from the bay of Mont S. Michel after a hurricane on the 9th of January, 1735, and its sands have been penetrated more than 50 feet in several places without reaching their bottom, though it is well known that previous to A.D. 709 the whole bay, as far as Chausey rocks, and for a considerable breadth northwards as far as Cape la Hague, and the country southwards as far as Dol, was the forest of Scisey. The positions of four ancient monasteries and the Bourg of Lhan-Kafruth, which stood in this forest, are known. One of these stood where there is now a sounding of 54 feet at low water, and the greatest rise of tide is also 54 feet, to which add 10 feet for supposed height of the monastery above high water, and we have a total of 118 feet of sinking. If the late Abbé Manet's figures are to be relied on, the Mont was once 176 English feet higher than it is now. It is certain, from the nearly contemporary records contained in 'Acta Sanctorum,' Dom Bouquet's 'Historians of France,' 'Neustria Pia,' and other middle-age authorities, that Mont S. Michel, which contains now only about 20 acres, was immediately previous to A.D. 709, 6 miles long by 4 miles broad and covered by forests; and that the rock was once a *Mountain*, and 6 miles, or, according to other accounts, 8 miles from the ocean, and even much more. A large tract of land 20 miles long, and in some places $2\frac{1}{2}$ miles broad, now lost, extended from Cancalle Point, past S. Malo to Cape Fréhel. There have been about nine different sinkings.

The remarkable *angularity* of the vast tracts of marine rocks on the south and west of Jersey, though daily subject to the action of the tides, can only be accounted for, he thought, by their having only been exposed to that action since 1356, at which date the tracts sunk, and the soil upon them was washed away, and the angles of the rocks have not yet had time to become rounded. Poingdestre, a learned antiquary born in Jersey in 1609, substantially confirms some of these views in No. 5417 of the Harleian MSS., which is known to be of the date 1685. The Ecrehous and Dirouilles on the north-east of Jersey are known to have been much more extensive than at present; they also sunk, probably in 1356. Ptolemy gives latitudes and longitudes in his own way, and some of them having been reduced to modern latitudes and longitudes, give important corroborative results. For example, taking his Oerinum promontory (the Lizard), and his centre of the Isle of Vectis (Wight) as points of departure, his Gobæum promontory of the Oëismii becomes $4^{\circ} 51' 21''$ W. long. and $48^{\circ} 33' 18''$ lat., which nearly coincide with the present north-western angle of Brittany, and therefore prove that in this instance

Ptolemy is nearly correct. His harbour of Staliocanus becomes $2^{\circ} 48' 81''$ W. long. and $48^{\circ} 38'$ lat., which nearly agree with the position of the present harbour of Portrieux, and are probably approximately correct. And, now observe, his mouth of the river Argenis becomes $2^{\circ} 0' 91''$ W. long. and $48^{\circ} 52' 54''$ lat., which give a position *seventeen miles west* of the present west-coast of Normandy, which is curiously corroborated by two modern writers (each independently of the other) having stated that Mont S. Michel was once ten leagues from the sea, which is the distance from the Mont to the mouth of the river Argenis, nearly. Observe also, the mouth of the river Tetus becomes $2^{\circ} 22' 2''$ W. long. and $49^{\circ} 2' 21''$ lat., which fall *more than thirty miles west* of the present west coast of Normandy, and range very well with Rigdon shoal and Great Bank, formerly forests. He believed Jersey was not an island until after Ptolemy's time. There had been a sinking of about 20 fathoms at the Northern Channel Islands; and sinkings along the French coast of the Bay of Biscay; but the Aunis has risen a few feet.

A large collection of contemporary and personal observations, and of facts from modern, mediæval, and classical history, all point in one and the same direction, namely, to establish the certainty of the changes indicated, and several others. Extracts and abstracts from this collection appear in the 'Artisan' of April, May, &c., 1866.

The Insulation of St. Michael's Mount in Cornwall.

By W. PENGELLY, F.R.S., F.G.S., &c.

St. Michael's Mount is an island at every high water, and, with rare exceptions, a peninsula at every low water. It is about one third of a mile from the mainland. Its name in the ancient Cornish language—"Caraclouse in Cowse," or the "Hoar Rock in the Wood,"—is entirely inappropriate at present, and betokens a change in the geography of the district since Cornwall was inhabited by a people speaking a language which survived until a very recent period.

The Mount is undoubtedly the "Ictis" of Diodorus Siculus, whose description is still so very appropriate as to render it probable that two thousand years have produced very little change.

The insulation must have been effected, of course, either by the encroachment of the sea or by a subsidence of the district. The former hypothesis requires such an enormous amount of time, and is so utterly opposed to various geological facts, as to render it eminently probable that, since Cornwall was inhabited by a race speaking the British language, St. Michael's Mount was insulated by a general subsidence of the country.

A Recent Example of the Formation of Pyrites in a South Staffordshire Coal Pit. By LOVIBOND PERCIVAL.

The example, which was interesting as tending to throw some light on the formation of pyrites in the coal-measures, and further, as having very recently occurred under definite and known conditions, occurred in a West Bromwich coal pit, which was opened about twenty-five years ago, and after a time was closed on account of the rise of water: it remained closed for seven or eight years, and on resuming work, some slack, which had been left in the pit, was found to be largely permeated by a peculiar formation of pyrites. In this case there had probably been a decomposition of pyrites (previously formed), and again the decomposition of the ferruginous salts in solution, by the presence of carbonaceous matter. The quantity of conglomerate of slack and pyrites thus produced was very considerable.

On Glacial Striation. By Professor PHILLIPS, LL.D., F.R.S., F.G.S.

On few subjects, amidst some apparent differences, are geologists better agreed than on the general theory of the movement of glaciers on their inclined beds in the Alps, while on their former and permanent effects, as evidenced in the valleys and among the lakes of England, the differences of opinion are great. The author believed that these differences ought to be brought to the test of accurate mechanical principles, such as the limits of effective pressure to move ice forward on level

surfaces and up ascending slopes; and confronted with accurate notions and exact maps of definite tracts selected for study. He then described the special phenomena which had been observed by Mr. Lee and himself, on a swelling ground at the foot of the Görner Glacier. In this case he showed that beautiful striation and polish were traceable on broad flat surfaces (protected by a shed) 150 feet above the actual bed of the glacier, and about 100 yards from its base. He showed that this was quite consistent with the known physical constitution of ice, and the slopes of the ground, steep as these are. It is quite clear that on such ascending slopes the upward movement of the ice, by pressure from the higher parts of the glacier, is a real and necessary result. That the glacier formerly extended much beyond its present limits is well proved by other facts. The author next described the phenomena of glacial movement in Wastdale, and the features of Wastwater, a deep straight lake, three miles long. In these can be shown the reality of partial movements of ice in the valley, but from the great length of the lower, almost level tracts of ground, and the shortness of the upper snow slopes in ancient days, he concluded that effective pressure could not be continued through the length of Wastdale. Among other reasons for this, he instanced the fact that under the pressure equivalent to 1000 or 1500 vertical feet of ice, that substance would lose its solidity. He also showed by a study of the relative grinding force of the icy weight under different conditions of depth and inclination, that if such pressure could be communicated, it would not be effective in excavating the lake. It would not tend to make a hollow such as a lake would fill, nor to deepen such a hollow if previously placed in its path in Wastdale. On the whole, he concluded that for a satisfactory explanation of the full wearing and excavating effect of ice in valleys and lakes it would be necessary always to treat each case as a special problem, by no means purely geological, but including important and quite practicable mechanical determinations.

On the Geology of Coalbrook Dale. By the Rev. W. PURTON.

Just where the valley of the Severn contracts towards the narrow gorge through which it passes the limestone ridge of Wenlock Edge, it is joined by the lateral valley of Coalbrook Dale, running down from the high table-land which forms the chief part of the Shropshire coal-field. The Dale, which is for the most part scooped out of the Wenlock shale, is joined about midway down by the hollow through which the railway ascends to Lightmoor, and which is excavated in the Lower coal-measures here faulted down: and is flanked at its entrance into the Severn valley by the Mound called Strethill on the north, and by Lincoln Hill on the south. At Strethill, we find the mass of glacial drift, 200 feet high above the Severn, which formed the subject of Mr. G. Maw's paper read before the Geological Society, and printed in their Quarterly Journal for May 1864; and which has served to prove that at one time during the glacial epoch Wenlock Edge was the coast-line of the Irish Sea, and the Severn valley a marine strait. At Lincoln Hill the Wenlock limestone, which rests at a high angle on the shale, is now worked in a series of extensive caverns; but in the old surface workings we may still see the cavities whence the Ball-stone has been extracted, as described by Sir Roderick Murchison in his 'Siluria.' And there is also exposed a highly interesting section, showing the Lower coal-measures resting immediately on the Wenlock limestone. The lowest seam of coal, the "Lancashire Ladies," and the "Crawstone" ironstone are visible. A walk along the south side of the Dale, about a mile, brings us to Lightmoor Wood, in a quarry in which the fossil tree was found which was figured some time since in the 'Illustrated London News.' In this quarry we again met with the Crawstone ironstone, and are able to trace the series of strata upwards to the "Little Flint" coal and "Clod" coal; while in the Lightmoor railway-cutting close at hand, we have exposed no less than six different seams of coal capped by the "Pennystone" ironstone. In a brick-field about 100 yards to the north still higher strata are exposed; and thus in a walk of little more than a mile, we may see in open sections the whole of the Lower coal-measures, and a portion of the Upper. It is to these sections I wish to direct the attention of those Members of the Association who are about to visit Coalbrook Dale. For a detailed account of the Shropshire coal-field, the estuarine character of its strata,

its peculiar fossils, including several species of insects, and of the *Limulus* or King Crab, I must refer them to Prestwich and Hull, and the Memoirs of the Ordnance Survey.

On the Recent Discovery of Gold at Gwynfynydd, North Wales.

By T. A. READWIN.

Notes on the Theory of Repulsion as illustrative of Physical Geology propounded by Dr. Winslow of Boston. By GEORGE E. ROBERTS.

On a Fossil Spider lately discovered in the Coal-measures of Upper Silesia (Prussia). By Professor FERD. ROEMER, of Breslau.

The author exhibited the specimen itself to the Section. It lies extended on the surface of a piece of coal-shale, and is beautifully preserved. Besides the outline of the body, it shows distinctly the four pairs of legs, and the two palps with their articulations. Even the coriaceous integument of the body, and the hairs attached to the legs are preserved. The interest of the discovery of this spider lies in the fact, that hitherto spiders were not known from any rocks older than the Jurassic, and that now their existence in the Palaeozoic rocks is proved. From the resemblance to the recent genus *Lycosa*, and its occurrence in the Coal-measures, the name of *Protolycosa anthracophila* was proposed for the species.

On a Coal Field in Brazil. By G. R. RUMNEY.

Explanation of a Map of the Faults in the Gold District of Dolgelly.

By J. W. SALTER.

The district examined during the autumn of 1864 included the greater portion of the right bank of the Mawddach river, from the waterfalls above Dolgelly to the Clogau Gold Mines nearer Barmouth, and advantage was taken of the dry weather in September and October to search the watercourses for evidence of the faults which cut up the mining region. Particular attention was paid to the portion about the waterfalls, and a few miles south. The results showed that while the major lines of fault ranged with the strike around the nucleus of Lower Cambrian rocks, and repeated the beds, thus widening the area of the Lower Lingula flags, the other faults, which are very numerous, and have not yet been shown on any map, are reducible to three or four series, the order being as follows:—

1. A series of east and west faults (Clogau, Gwynfynydd, &c.) of small amount, bearing quartz lodes and visible gold, copper blende, galena, iron, arsenic; these are crossed by—

2. Faults, rarely of large amount, about 30° or 40° north of east, occasionally, as at Cefn Coch (Welsh gold mines), rich in the precious metal, but also as at Cwm-heisian lead mine, with lead, or at other places copper, &c.

The above two series may be of one age; and are certainly the oldest. They have reference probably to the first undulations of the North Welsh district, and which run in a north-east and south-west direction.

3. Strike faults, following the outline of the Lower Cambrian nucleus (the Merioneth anticlinal of Professor Sedgwick), and hence varying in direction, more northerly on the upper waters of the Mawddach, more easterly along the estuary. Parallel faults to these occur in the great porphyry range of Arran, and of Cader Idris, and are marked on the Survey map.

4. North-west and south-east faults, of no great amount, usually as copper or lead lodes, but often bearing gold, (Tyddyngwladis silver lead mine and Dolfrwynog gold mines are examples). They are numerous, and as yet only known near the waterfalls, and thence to Dolfrwynog.

5. A grand series of north and south faults, usually 15° to 18° west of north, which cross and interrupt all the foregoing series, shifting the lodes and cross courses and giving the features to the ground throughout the whole of the gold mining districts. These are traceable by cliffs and ravines, river and brook courses, ledges

and steep escarpments, from Pistyll Cain, and far northward they extend to Clogau and Vigra mines, and are especially to be noticed in the Great Lower Cambrian nucleus of the Merioneth anticlinal, defining the north and south ridges of the mountains, and the great Trawsfynydd valley. This series of faults is the latest, and is probably of very wide extent—the north and south valleys of the Lake district in Westmoreland, and the great north and south faults of the carboniferous series in Lancashire, Yorkshire, &c. being very probably included in it.

All the above faults are of course connected by short cross faults at the angles of intersection; and the author believes that to this cause are due the minor lake valleys of North Wales, which, so far as he has examined them, seem always to lie in the lines of intersecting faults.

The author is not so certain of the exact order of the series 3 and 4, as he is that the east and westerly faults and lodes, containing gold, are the oldest; and the north and south faults the newest in the district.

That the ascertaining of the principal lines of fault, and their order of succession, must be of value to the practical miner in any given district is obvious enough; and it behoves those engaged in such operations to ascertain, as has been partly done in Cornwall, the relative age and contents of each of the series. If lodes be in lines of fault, as they certainly are, it is of consequence to the owners of mining property to ascertain what is the number and direction of any given series, containing, for instance, zinc and gold, and whether the slides and cross courses which interrupt and often spoil these may be advantageously searched for lead, silver, or copper.

There are eight series of faults known in the Cornwall districts and in Germany, as we learn from Sir C. Lyell's Manual. And the contents of each series are in part known; but it must be borne in mind that each successive crust movement, while it opened fissures for the metals of its own age, would by reopening the old fissures, tend to redistribute their contents, and possibly to commingle them with the deposits of newer age. The whole subject, as it is one of great scientific interest, so also demands very careful observation, the result of which will certainly be to diminish mining risk, and increase the sources of our metallic wealth; for faults and the lodes that accompany them are extremely numerous and definite in direction.

On the Drift in the Parish of Exhall, North of Coventry. By A. STARTIN.

In this paper the author pointed out the existence of a strictly local stream of northern boulder drift about two miles wide, passing from north to south over the centre of the parish of Exhall, and showed that although the drift overlying the country to the eastward, from the evidence of its fossils, was undoubtedly derived from the Lias, the Oolite, and the Chalk, and that on the high land at Corley, and the whole district to the westward being rounded quartzose pebbles and small gravel, was probably brought from the Bunter conglomerate of Staffordshire, yet that this drift-stream consisted almost entirely of angular fragments and large boulders from the Millstone-grit, and detritus from the coal strata outcrop between Nuneaton and Atherstone, only from 7 to 10 miles to the northward. He produced specimens from the drift, and also from the rocks *in situ*, and explained that the carboniferous strata and millstone-grit at Hartshill, a short distance to the north of Nuneaton, dip to the S.W. at an angle of 40 degrees, and form an elevated escarpment about 600 feet above the sea, overlooking the plane of the New Red marls to the eastward. From the sharp angular character of the boulders, and also from the fact that no marks of striation have been observed, he expressed an opinion that they had been probably carried southward by coast-ice during an epoch when the high lands of the Warwickshire coal-field formed an island in a shallow sea, and he suggested that the necessary contour of the supposed coast-line would account for this drift-stream being found in its present position.

On some Ancient Drifts and Old River Beds of Siluria.

By the Rev. W. S. SYMONDS, F.G.S.

The author stated that, as far as his experience extends, there are no stratified

deposits in the West of England which represent that preglacial period known to geologists as the Forest of Cromer period, which preceded the great general submergence of a large portion of Europe and the British isles beneath the waters of the glacial sea. The nearly total submergence of Siluria and Wales during the marine glacial period he considered as proved by the position of marine shell-bearing drifts, containing large ice-worn erratics, upon mountain platforms in Wales. These drifts have been found in several localities at the height of nearly 2000 feet above the sea. The conclusions arrived at by Sir Charles Lyell, Professor Ramsay, and others, are well known, and they all tend to prove that large portions of Wales and Siluria were submerged during a period of the glacial epoch, which may be denominated as the *glacial marine* period. If this was the history as regards North Wales, Mr. Symonds contended that it applies also to South Wales, almost the whole of which he believes to have been submerged during this glacial marine period. Accompanied by his friend, the Rev. James Hughes, he had crossed the hill of Craig Turch this summer, where the river Cothi rises, halfway between Llandovery and Tregarron, among the wildest scenery of South Wales. Here he observed large erratic rocks resting on drift similar in position to those of the Maenbras below Snowdon; and he believed these erratics to have been transported from afar by ice-rafts floating over a glacial sea. The hill platform of Craig Turch, like that of Moel Tryfaen, and the Snowdon country, had been elevated, in the course of ages, to its present height. In the accumulation of the marine drifts of the Snowdon country there could be no doubt about their origin, for they contain numerous sea-shells, and many striated, polished, erratic blocks, which must have been dropped into them by floating ice. The author thinks some of the more elevated mountain platform drifts of South Wales must be attributed to the same origin, viz., a *glacial marine* origin; but while believing that there are unmistakeable proofs throughout Siluria of long periods of submergence and of gradual elevation, as proved by the position of marine boulder-bearing drifts at different elevations, the author maintained that the effects of *land-ice and snow* in transporting great masses of local rocks to long distances had not been sufficiently observed. He had observed deposits of transported rocks so peculiarly local that it seemed impossible to suppose they could have been left by icebergs or rafts. No geologist could explore the valleys of the Wye, Severn, Usk, Towy, Tivy, Cothi, Rheidol, Yswith, Teme, and Lugg, without observing that the heads of those valleys were at one time filled with unstratified boulder-clay or till, and that through this *till* the rivers have excavated their channels. This till is entirely unlike the stratified boulder-bearing silts of marine origin. The boulders contained in this till are all local, are frequently elevated above all signs of even the most ancient river-action, have never been acted upon by water-action of any kind, and, though belonging to rocks *in situ* in the district, have been carried across particular districts and down particular hills; while as regards the erratics borne by floating icebergs they are mingled and heterogeneous. On many hills in Wales you observe boulders of entirely local origin studding hill-sides and resting on rocks to which they do not belong; but they have a local distribution, and have been derived from a local centre. He had observed also that in numerous instances the transported rocks never crossed a valley, as in the case of Dean Forest, where masses of millstone-grit and mountain limestone are found on one side of the valley, but not one can be found on the hills across the Wye. The whole tendency of Mr. Symonds's paper was to show that since the elevation of the land into its present condition, glacial land phenomena were continued long after that elevation, and that although there are evidences of marine glacial action, those evidences have been much obliterated and destroyed by the long-continued and later effect of *land-ice and snow*. He attributed the transportation of the masses of subangular gravel, which contains large erratics from the Malvern range, and are distributed in patches on the Hanley and Castle Morton plains, to the effect of a mass of frozen snow and ice which in former days stretched from the Malverns down to the plains. The ancient river-terraces of Siluria are well marked, and stand out in some instances at a height of 800 feet above the existing river-channels. In Worcestershire it is difficult to make out where the marine conditions ended and the river conditions commenced.

On Contortions in the Chalk at Withingham, near Norwich. By J. E. TAYLOR.

On the Agyates found in England, with specimens from different countries.

By PROFESSOR TENNANT, F.G.S.

On the Nodules in the Limestone of Wenlock Edge.

By the REV. J. D. LA TOUCHE.

The Wenlock is a well-marked stratum of limestone, of which one of its chief characteristics, wherever the author had an opportunity of observing it, is its tendency to become nodular, but it is near the town of Wenlock that these concretionary masses assume a remarkable importance at intervals along the Wenlock edge; here, about 700 feet high, buried in the substance of the general stratum, which is some 30 or 40 feet thick, are huge masses of limestone, locally called ball-stones, of a purity very superior to the surrounding rock, so superior that they are extensively used as a flux for iron ore. They appear to consist of greenish-grey veins mixed irregularly with bluish-grey limestone, and fossils are occasionally found in them. They vary in size from a few feet to some 50 feet in thickness, and their length, which is generally at right angles to the line of the ridge, is in some cases more than 100 yards.

That they have been formed subsequently to the deposition of the rest of the stratum seems to be proved, by the arching over them to a slight extent of the rock above, and in one instance a similar appearance had been observed in that which is below them. The rest of the surrounding stratum seems to be continued into their substance, in which but very slight traces of stratification are observable. That they have been formed subsequently even to the upheaval of the whole neighbourhood and its denudation seems probable from the fact that there is no indication of their existence on the surface of the Wenlock Edge, which there would be had they been submitted to the same denuding forces as have acted on the surrounding rocks, from which they differ greatly in hardness and composition.

On the Faults in the South Staffordshire Coal Field, and their relation to the Igneous Rocks of the District. By C. TWAMLEY.

A few Notes on the Structure of the Matterhorn. By EDWARD WHYMPER.

When one observes the great peak of the Matterhorn at a short distance, it is seen that its rocks are separated into three great divisions, of which the middle mass is the largest, and grey in colour, while the upper and lower sections are apparently of a dull red. On ascending the mountain, these divisions are clearly apparent, and the junctions of the sections are so marked, that it is almost possible to see the lines of separation. The rocks of the upper and lower divisions, however, it is found, are by no means uniformly red in colour, but are interspersed with others of a green and of an iron grey. It is from the red rocks being so much more positive in tone that they present a uniform tint when seen at a distance.

The specimens collected comprise fragments from each of these divisions. Those taken from the highest of the three divisions and from the summit (mica-slate, chlorite-slate, and quartz) were detached when collected, but the others were broken from the living rock. The middle and largest division is found to be composed chiefly of chlorite-slate; mica-slate, with seams of quartz coloured by oxide of iron, is found to predominate in the lowest division. Serpentine can be frequently found at the base of the mountain, but I have not observed it on the peak itself. The summit of the Matterhorn is a roughly level ridge of 350 feet to 400 feet in length. It is extremely precipitous on the south side; but on the side which descends towards the glacier of Zmutt the inclination is moderate, and it can be traversed with great facility. There are several little points on this ridge, and the highest of them is usually covered by a small cone of snow. The whole of the summit is covered with disintegrated fragments, and the living rock is not anywhere visible.

It was observed by De Saussure that the beds of the Matterhorn rise towards

the N.E. at an angle of 45° . This is scarcely exact, although correct on the whole. They dip towards the south and west; but the inclination towards the west is three times as great as it is to the south. In consequence of these dips, the plane surface of the beds presents a surface sloping downwards on the western and southern sides of the mountain, and the fractured edges overhang. It is mainly from this cause that so much difficulty has been experienced in all attempts to ascend the mountain until this year, and it was from observing this fact that I formed the resolution to attempt the ascent by the north-western face; for although it appeared smooth and unbroken, yet I argued that the fractures would fall in exactly the reverse manner to those which I have described, and this would render the ascent easy, even although the hold they might afford should be but small. The theory was correct, and the whole of the north-eastern face was found, in fact, to be a long staircase, with the steps shelving inward.

It is also in consequence of these steps that stones do not fall to any extent on the north-eastern side; it is evident that if any disintegrated fragments do break away, they must sooner or later be arrested on the ledges, and, indeed, I did not see any fall during the two days which I passed on the mountain. On the other sides, on the contrary, the Matterhorn rains down showers, nay, torrents and avalanches of stones both by day and night. Thus these dips become on one side a source of safety, but on all others of great danger.

We are enabled by a knowledge of these facts to account for the enormous moraine of the Zmutt glacier, which has attracted the attention and the curiosity of all observers; for the Zmutt and its tributary, the Tiefenmatten, sweep around the two faces of the Matterhorn on which we should expect the greatest masses of rock would fall. We find, moreover, that the Furgge glacier, which is below the N.E. face, has scarcely any moraine. The consideration of these facts also suggests naturally that we see nearly the primal form of the Matterhorn on its N.E. side, but that great changes have taken place on the others. We are sure, indeed, of this, for we see the fallen fragments below.

We can go a step further. The fallen masses are chiefly of the red rocks, and they must have either come from the upper or the lower of the three divisions. On the side of the Zmutt and the Tiefenmatten glaciers, however, the lower division is almost entirely covered by snow and glacier. We are forced, therefore, to the conclusion that they came from the upper; and it is doing no violence to the imagination to suppose that at some early period the now isolated obelisk of the Matterhorn was only the termination and the culminating point of the ridge of which the Dent d'Erin and the mountains to the south of it formed also a part.

On the ancient Glaciers North and East of Llangollen, and more particularly of the Neighbourhood of the Hope Mountain. By W. MATTIEU WILLIAMS, F.C.S.

In this paper the author described in detail the evidences upon which he bases his hypothesis of the existence of a large glacier, formerly occupying the elevated and irregular district lying between the north and east side of the valley of Llangollen, and the east side and south end of the vale of Clwyd, the present watershed of the river Alyn. The configuration of the district is peculiarly favourable for the formation and maintenance of a great glacier, and the remarkable course of the Alyn is due to this same configuration. On this account Mr. Williams has named it the "Alyn Glacier." The position of the large accumulations of moraine matter at the foot of the Hope mountain, in the neighbourhood of Mold, and all along the course of the Alyn, between Mold and Wrexham, formed the chief data upon which the extent and position of the glacier were determined. The decided indications of glacier-planing over the whole of the Hope mountain and the neighbouring hills, all of which are *roches moutonnées* of greater or lesser magnitude, and the existence of perched blocks, some of which are sufficiently remarkable to have become the subjects of popular legends, were pointed out.

Further and very decisive evidence of the course of the glacier is indicated by the composition of the boulders of the moraine heaps, and most strikingly by the boulders of the peculiar curly cancell of the Leeswood and Tryddn district, which

have been found in the drift many miles from their source, and in positions which they could only attain by ascending a considerable slope of the Hope mountain.

The sudden termination of the moraine mounds in a wide plain of drift, extending towards the present estuary of the Dee, and the general uniformity of level at which this occurs, were pointed out as marking the limit of the sea at the epoch of this glacier's greatest extension. Some mounds of drift upon this plain, apparently formed by the melting of icebergs in shallow water, were described; and the general phenomenon of the drift of this district was suggested as well worthy of careful study, in reference to the debated questions relative to icebergs *versus* glaciers, and the limits of their respective operations.

The paper is preliminary. The author announced his intention of pursuing the investigations further, especially to the southward and the westward of the ground already described.

On some Vegetable Deposits in the Aachensee.

By W. MATTIEU WILLIAMS, F.C.S.

The Aachensee, about thirty miles N.E. of Innspruck, is a very clear lake, with precipitous and richly-wooded banks. At the bottom of this lake the author observed an extensive deposit of trunks and branches of trees, evidently washed by storms into the lake. Many of these were standing upright, with roots attached and partially buried. They had assumed this position from having been washed down into the lake with some soil or stones still adhering to their roots. It was inferred from this that the upright position of fossil trees, even when the roots remained attached, does not necessarily prove that they have grown on the spot where they are found.

On examination of some of this submerged wood, it was found to be very dark in colour, and so dense that it sunk rapidly in the water. The annual rings separated easily like the layer of an onion, the cambium of each year's growth having apparently decomposed more readily than the rest of the wood. This was referred to as affording an explanation of the fact, that fossilized wood shows the original structure, even when all the wood has been replaced by mineral matter. The spaces between the rings would be first filled up in cases where deposition is occurring, and then the wood-rings would afterwards be replaced by further deposition as they gradually decomposed, and thus a series of concentric strata be formed.

Mr. Williams stated many reasons for supposing that, at the period of our coal formation, the British Isles had the configuration of an exaggerated Norway, a ridge or backbone of mountains, with deep wide inlets or fiords, some inland lakes, and many small outlying islands. With such a configuration, and a climate favourable for the rapid growth of any form of ponderous vegetation, the trees growing on the steep banks of the lakes and brackish fiords or estuaries would be continually washed down and settle in these basins, and thus form the coal-seams while the water remained clear. The dark-coloured and striped shales and rock of the coal-measures would be formed wherever the waters were turbid, and a mixture of mineral and vegetable matter was thus deposited together.

Mr. HENRY WOODWARD described and exhibited specimens of a new Phyllopodous Crustacean from the Moffat shales (Lower Silurian), Dumfriesshire.

These anthracitic shales abound in the remains of Graptolites, but other fossils are extremely rare. Two Phyllopodous Crustacea have been described from them by Mr. Salter, namely, *Peltocaris aptychoides* and *P. Harknessi*.

The new form closely resembles a *Discina*, but has a sector of $\frac{1}{6}$ th of its arc removed in nearly every specimen, the segment being separated from the rest of the disk-shaped shield by a line of suture. The shield is slightly conical, and ornamented with fine concentric lines; there is no dorsal suture as in *P. aptychoides*. A specimen from the cabinet of Mr. Carruthers shows the wedge-shaped rostral portion *in situ*.

The most perfect example measures 7 lines in diameter. The caudal portion is not preserved. The author proposed for it the generic name of *Discinocaris*,

with the specific appellation of *Browniana*, after Mr. D. J. Brown of Edinburgh, who first drew attention to it.

Mr. HENRY WOODWARD exhibited a new chart of Fossil Crustacea, showing the range in time of the several orders, with some recent types. [Designed and drawn by J. W. Salter, F.G.S., and Henry Woodward, F.G.S. Engraved by J. W. Lowry, F.R.G.S.]

This is the first palæozoological chart in which an attempt has been made to show, not only the separate geological formations, but the zoological divisions of the class. Each order is placed in a separate area, and the student can see at a glance when a group commenced, and where it ended, or if it be still existing.

A descriptive catalogue accompanies the chart, in which each order is briefly described, and the name, reference, locality, and formation given of every species figured.

On a Deposit near Lilleshall, Salop, containing recent Marine Shells.

By C. J. WOODWARD.

The deposit occurs in Fox-hill Field, New Lodge Farm, near Lilleshall. Fox-hill Field is a mound about 30 feet high, sloping equally on all sides. The whole of the mound is composed of moderately fine gravel, and on the north side are beds containing comminuted sea-shells, with a few specimens nearly entire. Lias fossils, much water-worn, granite pebbles, and subangular fragments of sandstone, curiously pitted on their surface, occur with the shells.

The following species have been found:—

Univalves.

Aporrhais pes-pelecani.
Buccinum undatum.
Dentalium abyssorum.
Fusus antiquus.
Nassa reticulata.
Natica clausa.
Purpura lapillus.
Scalaria communis.
Turritella communis.
Trophon Banfferis.

Bivalves.

Astarte borealis.
Cardium echinatum.
Cardium edule.
Cyprina Islandica.
Lutraria elliptica.
Mactra solida.
Mytilus edulis.
Pecten opercularis.
Pholas crispata.
Psammobia Feroensis.
Tellina (solidula) Balthica.

Cirrhopoda.

Balanus sulcatus (Scoticus).

The top of the mound is 463 feet above mean sea-level.

BOTANY AND ZOOLOGY, INCLUDING PHYSIOLOGY.

BOTANY.

On the Deodar Forests of the Himalaya. By Dr. CLEGHORN.

THIS communication consisted of a report upon the Deodar forests of the Western Himalaya, which he explored in 1862 and 1863, with a view of obtaining reliable information regarding the timber resources of the Punjab. The reports of Royle, Wallich, and other observers are most valuable as to the Eastern Himalaya, but there were no approximate data on record as to the area of inter-montane forest between the Jumna and Indus. A sketch map was exhibited, indicating the position and extent of the Deodar tracts, so far as ascertained between these rivers. He dwelt upon the applicability of the wood of the *Cedrus deodara* for railway purposes in the dry climate of the Punjab, where it has been found to be very valuable. A

series of photographs, by Col. C. Hutchinson, R.E., showing the characteristic vegetation of the Deodar and other Himalayan trees, were produced, and the average dimensions given. A forest officer is now employed upon each of the great rivers of the Punjab, for carrying out a systematic plan of conservancy and management of these valuable forests. The quantity of Deodar timber annually brought down the various rivers is now very large, and amounted to 12,000 tons upon the Chenab alone. A new and increasing trade in timber upon the Indus and Kabul rivers, important in its commercial and political bearings, was predicted.

The importance of conserving our Indian forests was first discussed at the meetings of the British Association in 1850 and 1851, and since then the subject had attracted great attention, both in England and in India.

Ranunculus radicans (Revel) as a British Plant.

By W. P. HIERN, M.A., Fellow of St. John's College, Cambridge.

Ranunculus radicans is a new name in British Botany. It undoubtedly grows in England; but it must be discussed how far it differs *specifically* from its allies. I discovered it at Silverdale in North Lancashire on the 16th of June, 1864, and have gathered it again this year in the same locality. *Ranunculus trichophyllus* (Chaix) seems to me to be most likely to be confused with this plant. The floating leaves of my plant serve to make a striking difference, inasmuch as Professor Babington states that *Ran. trichophyllus* has never been found in Britain with floating leaves. Moreover the fruit and other parts of the plant present distinguishing characters. I sowed some seeds of it in my room at college on 15th July last, and I have already (4th September, 1865) got a floating leaf. I have seen a small portion of a plant or plants from Belfast gathered this season, somewhat resembling my plant. The following characters of my plant serve to distinguish it from its allies, special reference being made to *Ran. trichophyllus*.

The fruit has a very convex keel below, and commonly the upper edge is more or less depressed towards the base and convex near the style: towards the depression thus formed, the transverse ridges on the achene mostly converge.

The receptacle is spherical, or nearly so.

The floating leaves are radiant, with lobes contiguous and often pedicelled.

The capillary segments of the submerged leaves are rather flaccid.

The stamens number from 15 to 18, generally 17.

The number of veins on the petals is about 7 at the middle, where the yellow colour ceases (and these subdivide at the margin into about 11).

The petals are contiguous, obovate, widened at the free end, contracted at the claw, and at least twice the length of the sepals.

The stem attains the length of from 1 to 2½ feet.

Upon sending a good specimen to Professor Boreau of Angers, I received a decisive reply. He says, I have no doubt but that the plant which you have done me the honour to send me belongs to *Ran. radicans* (Revel). The foliage is absolutely the same as in the plant that I possess from the same author! He also states that *Ran. trichophyllus* never has floating leaves, and that when these appear, the plant belongs to some other species.

In a paper on "the British Species of Batrachian Ranunculi," read before the Cambridge University Natural Science Society last October, I showed, among other things, that a convenient artificial method of classifying these plants was found to consist in exhibiting geometrically the position of each (sub)species, referred to two axes; the number of stamens which the (sub)species commonly has being measured in inches or other linear unit along one axis, and the number of veins on the petals being measured along the other axis. On fixing the loci of the (sub)species in this manner a remarkable law is observed: five of the most closely allied (sub)species, i. e. *Ran. Drouetii*, *trichophyllus*, *Baudotii*, *confusus*, *heterophyllus*, lie in one straight line; and the three next (sub)species, i. e. *Ran. peltatus*, *floribundus*, *tripartitus*, lie in another straight line which is near the former, and parallel to it. The parallelism can be shown on mathematical principles to express close affinity.

Now on placing the plant which is the subject of this paper after the same

fashion, it is found to lie on the former straight line, intermediate between *Ran. trichophyllus* and *heterophyllus*.

M. Revel, the author of the species, found the plant to remain constant during five successive seasons.

Whether it is considered as a distinct (sub)species, or as a variety of *Ran. trichophyllus*, I thought a notice of the plant would be interesting.

The paper was accompanied by several specimens and a drawing of the plant.

On the Identity of Origin of Starch and Chlorophylle.

By Dr. W. HINDS, Professor of Botany, Queen's College, Birmingham.

Whoever has devoted much time to the investigation of the internal structure of plants, must have often been at a loss to determine the exact nature of the various-sized granular objects which meet the eye. These granules abound in nearly all vegetable tissues, and vary in size from those of *Canna edulis* (or *Tous-les-mois* starch-granules), the largest known, to the vanishing-point of sight with high powers.

During several years of close examination of vegetable tissue, the author has endeavoured as far as expedient to divide these definable granular bodies into starch and chlorophylle granules, but the extreme resemblance in a vast number of instances between them, while it has been sometimes a source of perplexity, led to his examination of them with the view to determine how far these bodies were identical in their nature and origin. After a series of experiments and investigations, he arrived at the conclusion that these two series of granules must be considered fundamentally the same, one series being merely coloured or chlorized.

The grounds on which this conclusion has been arrived at may be thus epitomized.

Chlorized and unchlorized starches are found in the same organ in simple obedience to situation with respect to light. This is seen in the stem of the common and mature geranium. The granules are here found of the same size and form.

The same fact is seen in the case of the common potato tuber. Below the soil, all the granules are colourless; but, exposed for even a short period to light, the granules begin at once to become chlorized at the surface.

Even when detached from the plant and placed in a warm atmosphere with free exposure to light, this process of chlorization goes on rapidly. In the paper, of which this is a very short abstract, it is shown how this effect can be produced at will, and by covering over some parts of tubers, and leaving other parts exposed to light, chlorization printing in letter or ornament and in the negative may be produced. In the author's paper the subject of tests and reactions in reference to starch and chlorophylle granules is examined, together with the chemical features of the matter.

The solubility of chlorophylle colouring-matter is also considered, and the reason why ordinary chlorophylle granules are not sufficiently perfect to exhibit iodic reaction; in this respect, indeed, resembling the *acknowledged* starches which are found in such fruits as cucumber, and such roots as turnip and carrot, the starches in which will seldom show the proper iodic reaction.

The author concludes that unchlorized starch-granules will never be produced in the light, for immediately they acquire form and consistence, they become chlorized.

Also that chlorization will take place in dead, and therefore vitally quiescent granules, when under certain conditions they are exposed to light, and that therefore chlorization is a chemical, or at any rate not a vital process, as heretofore considered.

The almost universal green of nature is amylaceous, and can supply fuel, at least in the matter of food, to animals. Partly or wholly decolorized to the ordinary observer, as in shrivelled or dry grass as hay, the same amylaceous principle is yet present. The nutritive properties of hay which can support, of itself, animal life, cannot depend on the tissues alone, or on the fruits, which in the minor grasses are insignificant. On the other hand, amylaceous matters are known to be intensely nutritive, and those parts of plants in which this principle is concentrated are nutritive in proportion to the amount of that concentration.

On a Monstrosity of the Rose.

By Dr. W. HINDS, Professor of Botany, Queen's College, Birmingham.

The specimen introduced serves to illustrate the teratology of the tribe to which the rose belongs. It may or may not be unique, but it is at any rate one of the most rare transformations. Cases of the conversion of sepals into ordinary leaves are common enough, and are depicted by Balfour, Lindley, Bentley, and others. In the apetalous apple we have the petals transformed into sepals, or rather the required petals have developed merely as sepals. In the cultivated rose we have stamens merely developing as petals, and the carpels are imperfectly seen, or are converted into stamens, as described by Bentley. We have thus a *complete series* of transformations, with *two exceptions*. Of these, the first is supplied by the rose depicted in the 'Gardeners' Chronicle,' in which a *branch* (leaf-bud) and leaves have developed in the centre. The *second*, which completes the series, is now supplied in the shape of a *flower bud and peduncle* developed in the centre of the primary flower, instead of carpels. It seems to show that nature being interfered with has made a second effort to accomplish its ends.

At first sight this may appear to be one of the highest transformations, but a little consideration will probably show it to be one of the lowest. There is one lower, namely the *leaf-branch*.

Dr. JORDAN exhibited an abnormal growth of a bud of a birch-tree.

On the Relations of the Southern to the Northern Flora of New Zealand.

By W. LAUDER LINDSAY, M.D., F.R.S. Edin.

The North Island flora has hitherto been regarded, in the absence of an equally full knowledge of the South island flora, as correctly representing the general vegetation of our New Zealand possessions. But the New Zealand islands extend through 13 degrees of latitude, and the floras of their northern and southern extremes necessarily present various marked differences. The former flora is more *tropical*, and the latter more *antarctic* in its affinities. The former, moreover, is richer in natural orders, genera, and species.

Until very recently, however, comparatively little was known of the Otago flora, all collections previous to 1861 having been made on its *coasts*, and, with a single limited exception, on its *western* coast. In 1861, the author botanically examined the vicinity of Dunedin, and the settled districts between that capital and the Clutha river—all on the *eastern* seaboard of the province. The immediate fruits of this examination included (in the department of Phænogams and Ferns alone) out of a total of 235 species:—

A. 5 species new to science, or 2·12 per cent. of the whole.

3 not previously found in New Zealand or elsewhere.

2 previously found in certain other parts of New Zealand.

. 5 species not previously found in New Zealand, or 2·12 per cent.

1 sp. Antarctic.

3 — Tasmanian.

1 a native of Tasmania, Britain, and various temperate regions.

C. 22 species not previously found in Otago, or 9·36 per cent. of the whole, many of them previously supposed to be confined in their geographical range in New Zealand to the North Island.

D. 30 species rare in Otago or New Zealand, or otherwise exhibiting peculiarities of geographical distribution; or 12·76 per cent. of whole.

E. 25 species *British*, and indigenous in Otago; or 10·63 per cent. of the whole.

Of these, 10 species, or 40 per cent., are aquatics or semi-aquatics.

In addition to these, and to the total of 235 species, there were 27 species of British plants *Naturalized* in Otago.

Total Native 235

„ Naturalized 27

— 262 species.

Since 1862, the *interior* of Otago has been explored by the Government Geological Survey, and the collections made by the botanist attached thereto have largely added to our knowledge of the flora, more especially of its Alps and great lake basins.

The author's main object in this memoir, which is confined to the departments of *Phænogams* and *Ferns*, is—taking *Otago* as the type of the *South*, and Auckland of the *North*, Island—to institute a comparison between the floras of these respective provinces or islands.

The subject matter is stated in great measure tabularly and statistically as follows :

A. Differences.

| | |
|--|----|
| Group 1. Enumeration of Natural Orders occurring in North Island, but not in Otago | 22 |
| 2. Enumeration of Genera occurring in North Island, but not in Otago .. | 91 |
| 3. Enumeration of Genera occurring in Otago, but not in North Island .. | 10 |

B. Resemblances.

| | |
|--|-----|
| Group 1. Enumeration of Natural Orders common to North Island and Otago .. | 67 |
| 2. Enumeration of Genera common to North Island and Otago | 215 |
| 3. Enumeration of Species common to North Island and Otago | 581 |

C. Preponderance in favour of North Island.

| | |
|-------------------------------------|-----|
| Natural Orders | 22 |
| Genera | 70 |
| Species | 184 |
| Characteristic Northern Genera | 32 |
| „ Southern „ | 10 |

On the Propagation of Ferns by means of Spores. By E. J. LOWE.

ZOOLOGY.

On the Genus Anceus (Anceus and Praniza, Auct.).

By SPENCE BATE and PROFESSOR WESTWOOD.

After giving the history of this peculiar genus, the authors, while admitting the ability and general correctness of the recent researches of Mr. Hope, disputed his right to give the name of *Praniza*, which had been previously used as that of an adult animal, as belonging to a larval or young form only. They considered that to Mr. Hope belong the merit of having demonstrated that *Praniza* was the adult female of *Anceus*, but they differed from him in believing that the male *Anceus* ever was a *Praniza*, and showed that the two sexes passed through separate forms until each arrived at the adult stage; after which period they lose their parasitical character. That this change of condition is coeval with important structural alterations, by which both males and females lose their oral apparatus, together with stomach and alimentary canal. The mandibles in the male become large prehensile organs.

On the regard due to Usage and Utility, as well as mere Priority in fixing Zoological Nomenclature. By P. P. CARPENTER, B.A., Ph.D.

When generic names have come into almost universal use, and are good in themselves, it would save great confusion to allow them to remain. As in property, a certain number of years' undisputed possession might be regarded as a right. It is hard to give up such because it is discovered that an obscure writer badly named an ill-defined group a short time in advance. The new (so-called *old*) name might itself have to be displaced when some other antiquary had unhappily disinterred some older and worse book which had been fortunately forgotten. Surely use is the most complete publication.

Notes on the Voracity of Chiasmodus. By Dr. CARTE.

Dr. E. Perceval Wright exhibited for Dr. Carte a specimen of *Chiasmodus niger*, Johnson, which had been sent to the Museum of the Royal Dublin Society by Capt. Sir Leopold McClintock, R.N. The fish had been found by Dr. Imery floating on the surface of the sea near Barbadoes, with a species of the genus *Scopelus* in its stomach. The swallowed fish was nearly twice the size of the swallower, and the tegumentary covering of the abdomen of the latter was stretched as thin as goldbeater's leaf. A drawing of the specimen by Mr. N. Walsh of Dublin was also exhibited, showing the position of the *Scopelus* in the abdomen of the *Chiasmodus*.

On the Relative Weight of the Brain, and on the External Form of this Organ, in relation to the Intelligence of the Animal. By EDWARDS CRISP, M.D.

Dr. Crisp illustrated his paper with 126 casts in wax and plaster-of-paris of the brains of different species of animals taken by himself; among these, were the casts of the brain of the Chimpanzee, Orang, Gorilla, and of two species of Gibbon, and the cast of the brain of the Irish Elk (*Megaceros Hibernicus*), made by filling the skulls with plaster-of-paris; but many of the casts were from the brains themselves. The author thought that much error prevailed respecting the belief that the amount of intelligence corresponded to that of the number of the convolutions; he found that some animals with but few or no convolutions, as the Marmot, Rat, and many species of birds, had a large amount of intelligence; whilst many others, as the Ruminants, with abundant convolutions, were comparatively deficient in intelligence. The paper was further illustrated by a Table of 226 different species of animals, the bodies and brains of which (with a few exceptions as regards the body) were weighed by the author. As was well known, the brain of man averaged about 48 ozs. in weight, that of a woman 4 or 5 ozs. less, forming a proportion of about $\frac{1}{35}$ to $\frac{1}{40}$ of the body; but on looking over the Table, a great many animals among the Quadrumana, Rodentia, and Aves had relatively larger brains than man, but then it should be remembered that the brain in small animals, like most of the organs, was proportionately large.

The weights of the brains of a few animals dissected and weighed by the author, were as follows:—Young Chimpanzee (*S. troglodytes*), body 19½ lbs., brain 12 ozs. Young Orang (*S. satyrus*), body 20 lbs. 3 ozs., brain 10½ ozs. In a young Rhesus Monkey (*M. rhesus*), at birth, the body weighed 11 ozs., the brain 2 ozs. 20 grs. In a foetal Vervet Monkey (*C. pygerythrus*), body 8 ozs., brain 1 oz. 80 grs. In a foetal Hybrid Monkey, body 6 ozs. 325 grs., brain 500 grs. In a foetal Green Monkey (*C. callitrichus*), body 2 ozs. 184 grs., brain 196 grs. Chacma Baboon (*C. porcarius*), body 40 lbs., brain 6 ozs. 170 grs. Spider Monkey (*A. ater*), body 5½ lbs., brain 2 ozs. 10 grs. *Cebus apella*, body 2½ lbs. 5 ozs., brain 2 ozs. 10 grs. Marmoset (*M. vulgaris*), body 6 ozs., brain 166 grs. Vampire (*Desmodus*), body 8 ozs. 200 grs., brain 90 grs. Brown Bear* (*U. arctos*), body about 560 lbs., brain 13½ ozs. Lioness (*F. leo*), body 268 lbs., brain 7 ozs. Sea Otter (*M. lutris*), body about 30 lbs., brain 3 ozs. 160 grs. Porpoise (*D. phocaena*), body 60 lbs., brain 15 ozs. Seal (*P. vitulina*), body 40 lbs., brain 12 ozs. Capybara (*H. capybara*), body 45 lbs., brain 2 ozs. Harvest Mouse (*M. messorius*), body 111 grs., brain 6 grs. Armadillo (*D. sexcinctus*), 7 lbs., brain 295 grs. Young Tapir (*T. americanus*), body 148 lbs., brain 7 ozs. 380 grs. Elephant (*E. indicus*), body about 6720 lbs., brain 12 lbs. Giraffe (*C. giraffa*), body about 1790 lbs., brain 15 ozs. Harte Beest (*B. caama*), body about 336 lbs., brain 9 ozs. Aves:—Golden Eagle (*A. chrysaetos*), body 7¼ lbs., brain 260 grs. Raven (*C. corax*), 3 lbs. 2 ozs., brain 193 grs. Yellow Hammer (*E. citrinella*), body 420 grs., brain 8 grs. Gold Crest (*R. cristatus*), body 81 grs., brain 6 grs. Magpie (*P. caudata*), body 9 ozs., brain 96 grs. Heron (*A. cinerea*), body 4 lbs. 10 ozs., brain 138 grs. Maribou Stork (*C. maribou*), body about 16 lbs., brain 145 grs. Toucan (*R. toco*), body 8 ozs., brain 48 grs. Brush Turkey (*T. Lathamii*), body 4 lbs. 11 ozs., brain 45 grs. Young Ostrich (*S. camelus*), body about 60 lbs., brain 473 grs. Reptilia:—Hawk's-bill Turtle (*T. caretta*), body 12 lbs., brain 45 grs. Sand Lizard (*L. agilis*), body 113 grs., brain ¼ gr.

* This Bear was for many years at the Regent's Park Gardens, and I believe it was the largest ever seen.

Viper (*V. berus*), body 1 oz. 335 grs., brain $\frac{3}{4}$ gr. Pisces:—Pike (*E. lucius*), body 4 lbs. 6 ozs., brain 6 grs. Eel (*A. vulgaris*), body 3 lbs. 12 ozs., brain 1 gr. Cod (*G. morrhua*), 20 lbs., brain 55 grs. Portbeagle Shark (*L. cornubica*), body 40 lbs., brain 111 grs. Lamprey (*P. marinus*), body 3 lbs. 1 oz., brain 1 gr.

In the bodies of the larger animals ounces and grains are omitted.

From this, the *first* part of the paper, the author drew the following conclusions:—

1. That the EXTERNAL FORM of the brain alone in most animals is to a great extent an indication of the comparative amount of intelligence; but to this rule there are many exceptions, as in the examples of the Elephant, Dog, Seal, Rat, Marmot, and many birds.

2. That the same inference may be drawn from the covered or uncovered state of the cerebellum, as instanced by the last-named vertebrates.

3. That the number and figure of the convolutions are to some extent tolerable indications of the amount of intelligence in Mammals; but to this rule there are also many exceptions, as exemplified by a comparison of the brains of the Bats, Capybara, Rats, Mice, Monotremes, and many others.

4. That, looking to the weight of the brain and of the body in the 226 animals enumerated in the Table, and carefully selecting animals of the same class and size, it is evident that the most intelligent mammals and birds have the largest brains, and that there is no example of an animal with a relatively small brain that possesses a great amount of intelligence.

As the views of the author may be misunderstood in the above abstract the following from the paper is added:—

“As regards the number of the convolutions in relation to the amount of intelligence, I believe that much error prevails upon this subject. As is well known, the brains of Birds, Reptiles, and Fishes are without convolutions, and so with the brains of many Mammals. If we look to the ascending scale of Mammals, beginning with the *Monotremata* and *Marsupialia*, we find some of these with a greater abundance of convolutions than in the higher divisions; thus the Bats have smooth brains, and so have most of the Rodents; many of the latter, the Mouse, Rat, Beaver, and Marmot, possessing a great amount (comparatively) of intelligence, whilst the Capybara, an animal with several cerebral convolutions, is apparently one of the most stupid of the class. The brains of the *Edentata* are smooth, whilst many of those of the *Marsupialia* are convoluted to a certain extent. Again, the Carnaria, Ruminantia, and Pachydermata are abundantly supplied with convolutions, but many animals in these divisions are very deficient in intelligence and docility.”

On the Food and Habits of the Mole, Sparrow, and of the Vespidae.

By EDWARDS CRISP, M.D.

For many years the author has been endeavouring to ascertain, by numerous examinations, the nature of the food of the mole and of the sparrow, and his examinations at various seasons have been so numerous, amounting to a thousand at least, of each of these animals, that he spoke with confidence respecting the correctness of his conclusions. The mole can scarcely be called an insectivorous feeder, for its food consists almost entirely of the common earth-worm. He had never met with a wire-worm in the stomach of any mole that he had examined. The sparrow is almost exclusively granivorous, and obtains insects chiefly for its young; but these, when compared to the quantity of grain consumed, are very limited. Of the dried gizzards of 100 young sparrows which were exhibited, it was seen that but few contained insects.

Hornets and wasps do a vast deal of good by destroying insects in all stages of development, as the author had an opportunity of seeing when he had kept the grubs and perfect hornets under large bell-glasses. He had, moreover, had an opportunity of watching hornets through a crevice in the door of a pigeon's locker, in which a nest was constructed, and the quantity of insect food consumed by these generally despised robbers was immense. Tables of the examinations of moles and sparrows at various seasons accompanied this paper.

On the External Form of the Hand and Brain of the Orang (S. satyrus).

By EDWARDS CRISP, M.D.

The injected brain of an Orang and the hand of an animal of the same species, formerly belonging to the Linnean Society, and believed by the author to be the largest ever seen, were exhibited by way of contrast with the same organs in man. The measurements of the Orang's hand were as follows:—

From the carpal joint to the longest finger 11 inches; across the palm 2 inches $\frac{1}{4}$ th; the metacarpus 4 inches; the middle finger 5 inches; the thumb 2 inches $\frac{1}{10}$ th; from the root of the thumb to the point of the index finger 9 inches.

By these measurements, it will be seen that the hand of this ape is longer by about 4 inches than the human hand, and about 1 inch longer than that of the largest Gorilla. In a large Orang, in the possession of the author, the measurement from the tip of each finger, when the arms are extended, is 7 feet 11 inches, and the same measurement in the animal in question must have been of much greater extent, exceeding that of any human giant.

The brain of the Orang, when compared with that of man, presents many important deviations, not only as regards size, but especially in the direction of the medulla oblongata, an important feature that has been apparently overlooked. In the brain exhibited, as in Dr. Rolleston's specimen, the cerebellum is not wholly covered by the cerebrum; and the same is the case in the brains of two Gibbons, casts of which were exhibited; but in the twenty-eight casts of the brains of various *Quadrupana* the cerebellum was in nearly all covered by the cerebrum. The difference in the number and figure of the convolutions, the want of lateral and anterior cerebral development, and the more vertical direction of the fissure of Sylvius have been pointed out by different observers. Another *very important matter* Dr. Crisp believed had been overlooked by all writers on this subject. As seen by the brains of foetal monkeys, and monkeys at birth, which were shown to the Section, it will be noted that the brain at this period is much larger than in the human foetus and child at birth; but it must be remembered that the apes and monkeys, unlike the child, and like many of the inferior animals, are able to take care of themselves, to a great extent, as soon as they are born, and at once evince a great amount of activity. The author controverted Professor Huxley's statement in his Lectures at the Royal College of Surgeons, "*that there was less difference between man and the anthropoid apes than between these and the lower Quadrupana.*" The existence of a penis-bone in these apes, the author held, was alone sufficient to disprove this conclusion; he hoped hereafter to adduce abundant additional evidence against this inference.

A Description of Two New Species of Aporose Madreporaria, from Guernsey.

By Dr. DUNCAN.

Mr. H. S. ELLIS exhibited some Tiles with Young Oysters.

On the Occurrence of the Bones of Extinct Struthious Birds in New Zealand in the same Oven with those of the Dog. By the Rev. F. HEWLETT.

Notes on the Development of a Deep Sea Sponge. By W. R. HUGHES, F.L.S.

The specimens, six in number, and each about the size of a large pin's head, were dredged in the neighbourhood of Torquay, in the month of July 1863, and were afterwards placed in an ordinary aquarium, consisting of a large round glass pan, having a bottom of three inches of sand, and holding about a gallon and a half of water. The aquarium was placed in a N.E. aspect, and the stones and shells in it were well covered with confervoid growth. The sea-water in the vessel was never changed, but fresh water was occasionally supplied to compensate for evaporation; it was always pure and limpid as crystal. The specimens continued to develope, and by the month of December 1864 had each attained the size of a large pea, and about this time two, which were originally half an inch apart, coalesced and further continued to develope. By an accident, in the month of February

last, a portion of this particular sponge was lacerated and partially detached from the shell on which it was located. The injury was gradually repaired, and in six weeks afterwards the sponge was as firmly coherent and attached as before the accident. The inhalent and exhalent processes went on chiefly at night, or when the aquarium was darkened. Dr. Bowerbank, to whom some of the other specimens were sent for identification, pronounced them to be *Halichondria suberea* (Johnston), *Hymeniacion suberea* (Bowerbank), and stated that "he had never known this species to develop itself in a vivarium before, its usual locality being on shells, &c., seven to ten fathoms deep, and he had only once found it between tide marks at Tenby." In the month of July last (two years after being taken) the sponge had attained the size of a bean, but died about this time, apparently from the effects of excessive confervoid growth, which prevented the free action of the oscula and pores. These facts are recorded as an evidence of the great practical value of the marine aquarium as an instrument for the study of similar phenomena connected with marine zoology.

Mr. W. R. HUGHES, F.L.S., exhibited in an aquarium specimens of *Lepidogaster bimaculatus* and *L. cornubiensis*. The first named is one of the smallest of British fishes, and one of the most attractive tenants of the aquarium. It is somewhat tadpole-shaped, does not exceed two inches in length, the colour is a delicate pink slightly speckled, but is subject to great change, dependent perhaps on the passions. The eyes are of a beautiful colour, not unlike (if such can be supposed) living opals set in an areola of burnished gold; and they probably have double vision, in consequence of the optic nerves simply crossing in their transit to the brain without any commissural communication. A curious feature and distinctive character of the genus is that they have the power of attaching themselves and firmly adhering to stones and old shells at the bottom of the sea, by means of a sucker composed of the union of the pectoral and ventral fins, and consisting of two cartilaginous plates surrounded by a fringe. The movement of this sucker is effected by largely-developed muscles springing from the vertebral chain.

On the Homologies of the Lower Jaw, and the Bones connecting it with the Skull in Birds, Reptiles, and Fishes. By Dr. G. M. HUMPHRY, F.R.S.

After pointing out the features which characterize the lower jaw in mammals on the one side, and oviparous animals (birds, reptiles, and fishes) on the other, showing that in the former it invariably consists of one bone only, or one on each side, whereas in the ovipara there are three or more bones on each side, Dr. Humphry indicated that these differences have relation to the functions performed by the jaw in the respective classes. In ovipara, fishes especially, the offices of the jaws are chiefly confined to swallowing, which is commonly done with a gulp, without any previous division or mastication of the food, and every facility for swallowing is afforded by subdivision of the bones and the widening the pharynx. In mammals, the jaws being employed in seizing, holding, tearing, as well as swallowing food, they are, for the purpose of greater strength, consolidated into one bone, which is firmly connected with the skull. The uniformity of this plan, in spite of certain departures in particular animals from the general functions thus assigned to the jaws, was adduced by the author as an illustration of the important principle in zoology that, though the construction of a part in any class is determined by the general function of the part in that class, yet the same plan of construction is found even in those members of the class in which the function is different.

Dr. Humphry then pointed out that, though the mammalian jaw consists of one bone only on each side, yet it presents certain distinct and prominent parts—the dentary, the angular, the coronoid, and the condyloid or articular parts—which obviously correspond with the separate bones bearing those names in ovipara, adding that if the *dentary*, the *angular*, and the *coronoid parts* of the one be regarded as homologous with the *dentary*, the *angular*, and the *coronoid bones* of the other, there is the strongest ground for believing that the *articular part* of the mammal is also homologous with the *articular bone* of the bird, the reptile, and

the fish—at any rate, that very strong reasons ought to be given before we are called upon to renounce that which, upon the face of it, is so probable.

The squamous part of the temporal bone to which the lower jaw is, directly or indirectly, invariably attached, is in mammals always composed of one bone, and developed from one centre, like the lower jaw; and like it, it consists of certain well-marked parts—a glenoid part, a squamous part, and a zygomatic part. Dr. Humphry believes that as in the lower jaw the component *parts* of the mammalian bone correspond with the several *bones* of the ovipara, so, in the temporal bone, the component *parts* of the mammalian squamous correspond with the separate *bones* of this region in ovipara; that is to say, the “glenoid” corresponds with, or is homologous with, the “quadrate,” the “zygomatic” with the “quadrato-jugal,” and the “squamous” proper with the “squamosal.”

By Cuvier, and most subsequent anatomists, including Owen, the quadrate has been regarded as the representative of the tympanic. In controverting this view, Dr. Humphry showed that neither in position, in function, nor in development, does the quadrate correspond with the tympanic. The tympanic bone is simply a part of the auditory organ, having no relation whatever with the masticatory apparatus. In the descending series of animals we find that the auditory organ becomes simplified, part after part disappearing, till, in the fish, a membranous labyrinth alone remains. And it is far more probable that the tympanic bone shares this failure, and dwindles or disappears, than that it becomes magnified and subservient to a totally different purpose. We are, moreover, prepared for its disappearance in the inferior classes by the very great varieties which it undergoes in mammals, which were pointed out in considerable detail. It was shown, as the result of dissection, that the quadrate does not commonly sustain the tympanic membrane, and that in many reptiles this function is performed by a distinct ring of bone resembling the tympanic bone of the mammalian foetus; and this ring, and not the quadrate, is really the representative of the tympanic bone.

Dr. Humphry next proceeded to examine the view propounded by Vogt, and adopted by Huxley, that certain of the ossicula auditus—the malleus and incus—are, in ovipara, modified and magnified so as to form part of the mandibular pedicle, in short, that the malleus becomes the articular segment of the jaw, and the incus becomes the quadrate. Such a transposition of parts, topographical as well as functional, as is implied by this view is not, the author believes, in accordance with the laws of development and morphology. Each organ, he observed, throughout the animal world, is made to bear its own burden, and by the developmental forces of its own parts furnishes the structures necessary to fulfil the requirements made of it in the different members of the animal series. The components of the eye are not transformed to the accommodation of the ear; neither can we think that the bones of the ear are transformed to the accommodation of the mouth.

The arguments in favour of the view referred to are founded chiefly upon development and the relations of the parts concerned to Meckel's cartilage; and Professor Huxley has laid much stress upon these relations in the pike. But Dr. Humphry maintained that, even in the pike, the articular bone of the jaw is, like the dentary bone, developed, not in and around Meckel's cartilage, but on its outer side, and is easily stripped off from it. Any homological inferences, therefore, deducible from this relation apply to the dentary bone as strongly as to the articular bone.

Dr. Humphry further showed, by the same kind of reasoning as in the case of the tympanic bone, that the varying conditions of the auditory ossicles in mammals, the coalescence of the malleus with the tympanic in certain cetaceans and in monotremes, together with the small size or absence of the incus in the latter animals, prepare us for the disappearance of those bones in the simpler auditory organ of ovipara. He combated the idea that the development of the quadrate in cartilage is any sufficient reason for regarding it as the representative of the incus, believing that the mode of development of a bone in cartilage, or from membrane, is not to be laid much stress upon as a matter of homological significance.

The careful consideration of the matter from a development, as well as from a topographical and functional point of view, convinced him that we must not suppose either the tympanic bone or any of the auditory ossicles to be represented by the

quadrate; but that it is far more probable that a subdivision of the temporal takes place, corresponding with the subdivision of the lower jaw, and of certain other bones in ovipara, and that the glenoid part is represented by the quadrate, and the zygomatic part by the quadratojugal. This view is, moreover, in accordance with the relations of muscles and nerves to the respective parts, and with the position of the quadrate and the glenoid.

An Examination of the British Lepidoptera, with a view to investigate the Origin of Species. By Dr. JORDAN.

On the Transformations of Chloëon (Ephemera) dimidiatum.

By Sir JOHN LUBBOCK, Bart., F.R.S., V.P. Linn. Soc.

The author commenced by observing that *Chloëon dimidiatum*, the subject of his paper, belongs to a group of insects (the Ephemeridæ), which has become a household word among us, as the type of a short life. The idea holds good, however, only if we consider exclusively the life of the animal in its perfect condition; but if we regard the whole duration of life from the time of leaving the egg until the moment of death, it is by no means so appropriate.

The larva, in the earliest stage observed by the author, is a minute, transparent, active creature, with a large head, a tapering abdomen, and two long caudal appendages. It spends about a year in the water, during which time it increases in size, and alters considerably in appearance. These changes, however, are produced quite gradually, the insect going through about twenty changes of form, each accompanied by a change of skin.

The antennæ increase in length and in the number of segments at each moult, and it is remarkable that this increase is not produced by a growth of the entire organ, but by a rapid development and division of the third segment, counting from the base. In the first stage the larva has no respiratory organs, either external or internal. After the first change of skin, however, the posterior angles of several abdominal segments become elongated, and after one or two more moults, these elongations have taken the form of the gills, or branchiæ, characteristic of the species. At the same time, the tracheæ make their appearance. So far as the author is aware, no other insect has yet been observed which is entirely destitute of tracheæ. After the first one or two moults, a minute knob appears between the two caudal appendages, and with each moult this knob increases in length, so that the larva which had originally two tails, finally possesses three.

After about eight moults have taken place, it may be observed that the posterior mesothoracic angles are slightly elongated. At each change of skin, these, the first rudiments of the wings, become more and more apparent, and in the last aquatic stage these rudimentary wing-cases cover the first two or three abdominal segments.

The external sexual differences commence to manifest themselves at the eighteenth stage. They consist principally of the rudiments of the pillared eyes, and of the processes on the under side of the penultimate abdominal segment, both of which are characteristic of the male sex.

The author then described the manner in which the larva quits the water, a process which does not occupy more than ten seconds. It is well known that the ephemeras pass through one more moult after acquiring their wings and leaving the water. The author described the principal differences between the pro-imago and the imago, or perfect insect, and concluded by some general observations on the subject of insect metamorphoses, laying special stress on the fact that, as was shown in this paper, the changes in the larva are not all in the direction, so to say, of the perfect form. Thus, for instance, the young larva has two tails; a third is gradually developed; but again the perfect insect has only the original two.

If we bear this in mind, and remember that external circumstances continually act upon the larvæ, that the form and characters of the larva have special reference to its own habits and conditions of life, we shall throw some light on the otherwise inexplicable fact that in some cases insects and other animals which agree very closely in their perfect condition have larvæ which differ a good deal from one another.

*On the Characteristics of the South Slavonic Race.**By Miss IRBY and Miss MACKENZIE.*

The writers of the paper contrasted the Slavonic characteristics with those of the Greeks on the one hand, and the Germans on the other. The Greeks were ambitious and irritable; the Bulgarians were contented and not easily roused to anger. The Greek was subtle; while the Bulgarian was strong in common sense and perseverance. The Bulgarians were especially devoted to the cultivation of the soil, especially in Servia, where they carried on a great part of the agriculture. They possessed a great respect for truth, of which the Greeks were entirely deficient. The poetry of the Slaves was very picturesque, but it lacked much of the great merit of that of the Germans. In art they were not altogether deficient, but the condition of the people precluded that cultivation of the fine arts which might otherwise have developed the tastes they undoubtedly possess.

On the Turdus migratorius. By the Rev. A. W. MCKAY.

This paper gave a minute description of the Red-breasted Thrush of North America, pointing out several particulars in which it resembled the thrushes of this country. It is a bird about the size of the common blackbird; the head, back, and wings being black in colour, and the breast and belly red, inclining to white about the region of the vent. Its note sometimes resembles that of the blackbird, especially when the bird is startled. Its song-note is much like that of the musical thrush of this country. The most remarkable peculiarity is in the colours of the plumage of the young bird, which is spotted like the permanent coat of the thrush. At the first moulting-season this plumage is cast off, and the ordinary red and black assumed. The bird is a universal favourite, for its familiar habits and the beauty of its song.

On the Arctic Highlanders. By C. R. MARKHAM, F.R.G.S.

The author said the people were found in latitude 76° and 79°, on the verge of the unknown polar region. The waters were crowded with seals, walruses, and whales, and great quantities of small fish. Here they might expect to find man existing; and there were actually about 140,000 souls scattered along the coast, of Asiatic aspect, as far as the outer man was concerned. They had no canoes, nor had they bows and arrows, but their sledges were superior to those of the Esquimaux. The hunting-season enabled them to accumulate large stores for winter use, but sometimes those failed them, and great hardships had to be suffered in hunting in January and February, and frequently they were reduced to eating their dogs. They, in common with the natives generally of that part of the world, had a wonderful talent for topography; they were very fond of liberty, possessed great powers of endurance, and were very brave. He thought they had been derived originally from the frontiers of Siberia.

*On Phosphorescence, Storms, and Disease.**By J. MOFFAT, M.D., F.R.A.S., F.G.S., &c.*

The results given in this paper were deduced from observations extending over a period of four years. It was asserted that phosphorus was luminous under the conditions of the south or equatorial current of the atmosphere, and non-luminous under the north or polar current; that it becomes luminous on the approach of storms, and that it becomes luminous, or, if luminous, it becomes more brilliant at the time that cautionary telegrams are sent out to give warning of approaching storms. The author believes that ozone is produced when phosphorus is luminous, and that there is a connexion between luminous and ozone periods, and non-luminous and no ozone periods. The commencement of these periods, and the approach of storms were stated to be accompanied by diseases of the nervous and vascular systems. Storms, however, are useful in a sanitary sense, as they ventilate fever nests and cholera localities. Dr. Moffat considers phosphorus an effective disinfectant, as a producer of ozone, and has used it as such for four years.

On the Scope of Conchological Inquiries. By Dr. MÖRCH.

1. The three continents, viz., 1. Europe and Africa; 2. North and South America; 3. Asia and Australia, owe their configuration to a definite plan, which can be traced in very old geological periods.
2. These continents represent three different formations, geologically speaking.
3. The old world is inhabited by the higher forms of each natural division, whilst the lower are found in the new world; *e. g.* the *Quadrumana* of the old world are higher in organization than those of the new world. The lowest mammalia are characteristic of Australia.
4. America is an island in the Atlantic Ocean, being in zoological respects limited by the abyss between the Galapagos and Sandwich Islands.
5. The limits of marine faunæ depend chiefly on climate.
6. Most species of one fauna have some characters in common, *e. g.* colour, sculpture, &c.*
7. Each fauna contains analogous species.
8. The lingual dentition is of the greatest importance in deciding whether the specific differences of univalve shells have arisen from external influences, such as saltness or depth of water, or originally existed.

On the Classification of the Mollusca. By Dr. MÖRCH.

1. The primary divisions of subkingdoms among animals cannot be founded on the locomotive organs, as proved in the case of Pinnipedia and Cetacea among Vertebrata.
2. Lungs and gills indicate only relative superiority and inferiority, but not the limits of systematic divisions.
3. The presence of respiratory organs depends only on the thickness of the skin or other protective coverings impermeable by oxygen.
4. The development of gills is dependent on the extent of the area impermeable by oxygen.
5. The form and size of the renal organ correspond with those of the gills.
6. According to the number of the auricles of the heart, the Mollusca are divided into two groups, Monotocardia and Diotocardia, analogous to Thelazia and Sicremia among Vertebrata. The former division has a copulatory organ, which is wanting in the latter.
7. Gasteropoda with a retractile male organ are androgynous.
8. Gasteropoda with an external but not retractile male organ are bisexual, with the exception perhaps of *Valvata*, according to Moquin Tandon.
9. The development of a male organ indicates relative superiority of the nervous system.
10. Great fertility indicates want of intelligence to provide for offspring.

On the Zoological Affinities of the Mollusca. By Dr. MÖRCH.

1. Radiata, in the sense of Cuvier, cannot be considered a natural division, being founded only on external form.
2. The Acalephæ have, in respect of external form, the same relation to the Acephala as the Cephalopoda to Gasteropoda; and they have, in respect of the gastro-vascular system, the same relation to Acephala as the Phleboterata to Gasteropoda.
3. The division of Entozoa is artificial like that of the Infusoria, being founded only on characters dependent on their habits.
4. The Platyhelminths have the same relation to Pellibranchiata as Linguatulæ to the Acari.
5. The locomotion of the Pellibranchiata is performed by the hind part of the mantle, the true foot being rudimentary only.

* Cf. *Malacozoologische Blätter*, 1859.

Remarks on some Improved Methods of Displaying Birds in Public Museums, illustrated by specimens from the Derby Museum at Liverpool. By THOMAS J. MOORE.

The author suggested that groups of birds should be so arranged that the male and female birds, their young, their nests, eggs, and the nature of their haunts might be seen at a glance, thus conveying to the non-scientific spectator an amount of knowledge that no collection of isolated specimens could convey.

On a remarkable Discovery of Bones of Didus in the Island of Rodriguez.
By EDWARD NEWTON, M.A., C.M.Z.S., Acting Auditor-General at Mauritius.

In November 1864, the author, in company with some other gentlemen, visited Rodriguez, and in a cave on the south side of the island (see 'Ibis,' 1865, p. 152) three bones of a species of *Didus* were found. These have been described and figured in the 'Proceedings of the Zoological Society' for 1865 (p. 199, pl. 8). Encouraged by this discovery, the author, after his return to Mauritius, requested a friend at Rodriguez to continue the researches, from which want of time had compelled him to desist. The result is contained in the following extract from a letter dated "Mauritius, 3rd August, 1865," and communicated by him to the Section.

"Two days ago I received from Mr. George Jenner, the Magistrate of Rodriguez, —to whom be all honour—a box containing Turtles' and Birds' bones. With pleasure I divided them, and found that of the latter there are remains of no less than sixteen or seventeen individuals! They are all apparently of one species, but of two sizes, the difference in this respect being probably owing to sex. The most plentiful bones are tibiae, of which there are two or three quite perfect, the antero-proximal ends being well preserved. There are also several very good femora and metatarsi, three portions of pelves (showing most conclusively that they did not belong to a Struthious bird), one anterior end of a coracoid (showing the same), several humeri of both sizes, an ulna and two radii, and a phalanx of the middle toe. Of these I believe that the upper end of the tibia, the portions of the pelvis and of the coracoid, the ulna, radius, and phalanx are bones which have not before been found, and are therefore doubly valuable. I retain here a couple of perfect legs of the two sizes for our Museum, but the rest I am sending home by this mail. It will be seen that there is one tibia which is much longer than any of the others; it is not a perfect one, but there is such a strong resemblance between them all that I feel sure they are but of one species. On reading over Mr. Bartlett's paper in the 'Proceedings of the Zoological Society' for 1851 (p. 284), I must say that I do not think he shows any good reason for supposing that the true Dodo ever existed in Rodriguez, or that remains of more than one species have been found in that island, and, now that I have examined these bones, I am still more convinced of the fact.

"I am writing to Mr. Jenner to beg him to look out for some of the smaller bones, which I feel certain must exist, and with any luck I think we ought to get a perfect skeleton some day."

On the Structure and Development of Salpa spinosa, Otto, as observed at Guernsey. By the Rev. A. M. NORMAN.

Phrenology, or the Physiology of the Brain, the most important department of Ethnology. By Dr. PRIDEAUX.

Remarks on a curious preserved Specimen of the Blackbird.
By P. O'CALLAGHAN, LL.D.

The author said that a boy had informed him that he had seen a cock blackbird with a top-knot; by his directions the habits of the bird were observed, and it was found that it had paired with an ordinary hen blackbird, and that they had built a nest. On the young being hatched, three of them were discovered to possess the top-knot by which one of their parents was distinguished, and it was one of these that was exhibited to the Section.

On the Birth of a young Hippopotamus in the Zoological Society's Gardens at Amsterdam. By P. L. SCLATER, M.A., *h.D.*, F.R.S.

The author remarked that three pairs of this huge animal were now living in different Zoological Gardens of Europe, viz. in those of London, Paris, and Amsterdam. Though the female in the Gardens in London had often shown signs of breeding, and attempts at copulation had been made by the male, it was not believed that conception had ever occurred. In the case of both other pairs, reproduction had already taken place on several occasions; but the new-born babe had always perished, either from the violence of its parent immediately after its birth, or from incapacity to take food when removed from its mother. The first successful instance of the reproduction of the Hippopotamus in Europe was therefore that which took place at Amsterdam on 29th July last, for the details of which Mr. Sclater was indebted to the well-known director of the Zoological Gardens in that city, Mr. G. F. Westerman. Copulation in the present instance had occurred on the 6th and 7th of December, 1864, so that the period of gestation was estimated at 234 days, which had been likewise confirmed in the previous cases of reproduction in the same pair of animals. As soon as the birth took place the little animal was removed from the mother, not without some difficulty, as the mother was already on her legs to defend it, and transferred to a separate house previously prepared for its reception. Here it is now thriving well and growing fast every day, taking every day six or seven meals, about $2\frac{1}{2}$ gallons of milk mixed with one-fifth part of water.

On the Occurrence of Oreyanus alalonga on the Coast of Devon.

By Dr. W. R. SCOTT.

The *Oreyanus alalonga* has but rarely been seen in British seas; one is recorded as having been taken at Portland, two in Mounts Bay in Cornwall, and this, another specimen, was captured on the coast of Devon, August 26th, 1865.

The full length of this fish from the nose to the base of the caudal fin was 24 inches; the girth round the pectoral fin 19 inches, and the girth immediately before the second dorsal $15\frac{1}{2}$ inches; the flesh in this part being very firm and solid. The head was pointed, the under jaw slightly the longest, the teeth small and incurved, and the gape about 4 inches; the nostrils very obscure; the eye large and slightly elevated and placed over the angle of the mouth. The sections of the gill-covers were well defined, and from the nose to the gill opening was 7 inches. The pectoral fin, lodged in a deep depression, was $8\frac{1}{2}$ inches long and reached to about the middle of the anal fin. There was a short space between the first and second dorsal fins, and there were eight finlets above and seven below. The anal and second dorsal fins were falcated; the tail deeply cleft, and the weight of the fish twelve pounds. The form of this fish was not so slender as that figured by Couch, and the length of the pectoral fin not so great, though fully up to the length given by Cuvier, who states it to be one-third the length of the body. This fish exhibited remarkable strength for its size, agreeing in this with the account given by the fishermen who captured the specimens taken in Mounts Bay.

On the extraordinary partiality shown by Insects of the Genus Laverna for Plants of the Order Onagraceæ. By H. T. STANTON.

The genus *Laverna* is a genus of moderate extent in the family *Elachistidæ* of the *Tineina*. The limits of the genus are not at present very accurately defined, and future investigation may show that its boundaries should be extended, so as to include some of the cognate species placed in allied genera. At present we have eighteen species in the genus, eight of which are distributed amongst plants of very different orders, occurring on *Typha*, *Tamarix*, *Pyrus*, *Crataegus*, *Quercus*, *Helianthemum*, and *Rhamnus*; the remaining ten species are restricted in their food to the *Onagraceæ*, and all feed on *Epilobium*, one species also feeding on *Circea lutetiana*. Three occur on *Epilobium angustifolium*, four or five on *E. hirsutum*, and two on *E. montanum*.

*On the Natives of Patagonia and Terra del Fuego.**By the Rev. W. H. STERLING.*

The mission to which the author belonged was stationed on Falkland Islands, and the mission ship coming to England for other purposes, it presented a favourable opportunity of bringing a few of the natives, four of whom were present in the Section-room. These natives belonged to the island of Terra del Fuego. There was undoubtedly an affinity between their race and the Patagonians, but the habits of life and the circumstances under which each lived were very different. The Patagonians were generally spoken of as giants; this was an error; forty of them had been measured, and their average height was about 5 feet 10 inches. The Fuegians were a shorter race. The Fuegians were very much harassed by the weather, for they had scarcely anything to wear besides a strip of seal-skin. Their diet was fish. They were canoe Indians. He had never discovered any traces of cannibalism, and even their taste for beef, mutton, and other flesh food had to be acquired.

On the Domestication of certain Animals in England between the Seventh and Eleventh Centuries. By J. THURPP.

This paper gave an account, derived from the actual examination of ancient documents, of the amount and character of the domestication of various animals in England during the period stated. First, animals thoroughly domesticated were noticed—horses, pigs, sheep and poultry. Secondly, animals imperfectly domesticated, such as goats, deer, hawks, &c.; and a third class, canaries, parrots, &c., which, when opportunity presented itself, would escape to savage life. The essay gave details of the domestication of the pig, with the laws and charters relating to its protection. Horses came next in the work of domestication, about the tenth century, when it was unlawful to ride on horseback, and even kings were accustomed to hunt on foot. This restriction was afterwards withdrawn, and riding, hunting, and fighting on horseback came into use. Bees were domesticated between the sixth and seventh centuries; and, being found very profitable, the nobles, clergy, and laity all combined for the protection of that insect. Hawks were next introduced, but with the introduction of fire-arms went into disuse. Weasels and cats brought the subject up to the eleventh century.

Dr. E. P. WRIGHT exhibited a copy of the 'Record of Zoological Literature for the Year 1864.'

PHYSIOLOGY.

Address by HENRY W. ACLAND, M.D., LL.D., F.R.S., *Regius Professor of Medicine in the University of Oxford.*

LADIES AND GENTLEMEN,—In addressing you from the Chair this day, I desire first of all to express my sense of the unmerited honour thus conferred upon me. When informed that it was intended to propose me as your Chairman, my first impulse was without hesitation to decline so great a distinction, in order that the post might be held by one of the many eminent persons who usually contribute to the success of the Section, or to the renown of the Department. Further consideration seemed to show me that the greater homage would be to place unreservedly at your service such humble powers as I have, and to offer you that which I possess, viz. the force of profound interest in the progress of one of the most important departments of human knowledge, and of sympathy all but lifelong with its promoters.

I rely, therefore, on the support which you will generously give to my endeavours to secure all full and fair discussion that is consistent with a due regard to the limited time at our disposal.

It has become a custom that the Presidents of Sections should make some

opening address, though it is held to be inexpedient that it should be elaborate or long. While debating on the subjects on which I might usefully touch, I chanced to encounter the remark of a philosophic writer, that the time was come when it was a prime necessity for Biology that it should be separated from Medicine. The grounds alleged were, the imperfect education of physicians, their want of leisure, and the magnitude of biological science. There seemed to me such a mixture of truth and error in the remark itself, and in the general tenor of the data on which it was founded, that it appeared to me well worthy of your attention.

As to the imperfect education of physicians, the remark is too general to be correct, and is not a topic proper to be considered here, further than to say, 1st, that it is to great medical minds, from Hippocrates and Galen down to Haller and Hunter, that we owe the promotion, and, indeed, the very creation, of a large part of existing biological knowledge, so that these men cannot have been ill furnished for their work; and 2ndly, that it is certain that no persons who are not well prepared will in future make any additions of importance to this or any other department of science. The observation, therefore, on the whole, amounts to this, that in these days biological science has become too extensive to be committed to the care of any but those who can give to it undivided attention. This also is only true under limitation. It is true so far as this, that division of labour is as necessary for the perfection of this portion of science as of others; and further, that some parts of biology are become so complicated and so extensive as to demand for original work the whole powers of any man of ordinary calibre. But it would be quite as just if we were to lay it down broadly, "There has been no period when it was as necessary for the progress of biology as now it is, that its relations with medicine should be closely maintained." Neither position would be wholly true, or, therefore, wholly safe. It may not be amiss to occupy a short time at the outset of our detailed labours with a brief consideration of the real scope of the pursuit in which we are engaged, and of the means which we possess for attaining our objects. I crave your indulgence if my analytical description fall short of your distinct conceptions or your more sanguine aspirations.

The objects of biological study are, unquestionably, as in most other sciences, *First*, simply to ascertain what are the facts in a certain department of Nature, with no regard to the practical consequences which can be deducible therefrom; and *Secondly*, but less directly, to discover the laws and devise the rules which are of various degrees of importance and value for the practical exigencies of mankind,—just as mathematical and physical astronomers investigate the facts which are necessary for the construction of the Ephemeris, and make it to be a work of equal value for the pure astronomer and for the practical navigator.

But some of the facts which physiology investigates, and the laws which it seeks to discover, happen to be of cogent consequence to all men equally,—to the thoughtful and the cultivated, because they have the tendency to illuminate the most hidden recesses of our mental constitutions, the most obscure traces of our origin, and our various correlations to other beings, animate and inanimate; to the mere "hewers of wood and drawers of water" among men, because it seeks to ascertain in the most precise manner the conditions of physical existence, to point out the work that can, and that cannot, be done upon such and such an amount of sustenance. In short, it seeks to define the exigencies of the human body in respect of all the external circumstances in which it is ordinarily placed, in respect also of all other physical agents that can act upon, or be acted upon by it; together with the internal chemical and physical alterations to which these several circumstances can, directly or indirectly, give rise. It has to learn also the limits of toleration within which the body is confined by these external agents, and the way in which these limits are regulated—as the laws of toleration of climate, of heat, of food, of various noxious agents, and many other particulars, of which the catalogue would be greater than that of the ships of Homer.

Every person, therefore, whether he knows it or not—the Statesman, who has to consider the sustentation of the people—the Religious man (that is, every one who believes in a moral government of the world, or hopes for a future state, and who has opinions on the history or origin of the Human Race)—the Animal man,

who prides himself on his strength, or whose strength is to him for a fortune—the Mother, rich or poor, who yearns by night and by day for the healthy growth of her tender offspring—the Physician or Philanthropist, who desires to avert or to relieve diseases among communities or individuals of men—each and all of these are alike really interested in the steady progress of the most abstruse philosophical speculations of the physiologist, as certainly as of the commoner rules of a healthy life, which are to be safely deduced from them.

In reference therefore to the opinion which was just now adverted to, I think that Biology is to be extricated from the hands of physicians only in a limited sense. No persons have so many grounds for advancing it as they. The physician, abstractedly considered, combines all the characters to which I have alluded. He is, in respect of the health of the people, a Statesman; as a Man, like others, a Religious man; not less than others, Father and Husband; as much as any, a Working-man; by education, more or less, a Man of Science. In short, abstractedly considered, I say it is his special duty at least to advocate and, if he can, to promote the advance of physiological knowledge *unfettered and free*,—

1st. As a pure Science.

2nd. As the basis of the Medical Art.

3rd. As of practical utility in helping to regulate the lives and habits of society at large.

Now the hindrances to a perfectly free study of Physiological Science arise from two causes:—

1st. The intrinsic difficulty of the subject; and

2nd. The prejudices of mankind.

To the consideration of these two points it may not be useless for us to devote some attention.

1st. As to the intrinsic difficulty of the subject.

Although the wisdom of this Association entitles this Meeting a *Sub-Section*, I am among the minority who cannot understand the force of the arguments which go to class Biology (which term may be now used synonymously with Physiology) as a subordinate subject. Being, when properly considered, the most complicated of all the subject matter debated at this Association, it cannot be really subordinate to any, least of all to Zoology and Botany, which it distinctly *includes*. It may be an open question whether Physiology be a branch of Physics and Chemistry; it is not an open question whether it includes the knowledge of the characteristics upon which the classification of all entities that are said to have life is based.

It were an impertinence, however, now to spend time in arguing about the Classification of Sciences. It is sufficient for us to note the vast range of Biology, a range which every year makes more wide.

The knowledge of the actions of living beings depends, and necessarily depends, not only upon what may be learnt intrinsically, so to say, in the living beings themselves, but upon the collateral advancing waves of physical and chemical inquiry. How largely, for instance, in the last few years, have the idea of Conservation of Force in Physics, and the remarkable advance of the Synthetical operations of the Laboratory affected our fundamental conceptions of the actions in living bodies, and increased the chances of our advancing a step towards the knowledge of what is essential in the phenomena which we designate Life.

The intrinsic difficulty of this search in the present day consists not so much in the morphological examination of beings, on the one hand, as complex as Man with all his varieties, and the problems thereto attaching (though this morphological examination of Man in all his varieties is still incomplete), nor in the examination, on the other hand, of beings so inexplicably simple as our own *Amaba*, or as the ancient (and how ancient!) *Eozoon Canadense*, but in the causes and conditions of the actual or potential changes in the minutest portions of any one creature. The labours of Goodsir and Virchow and Beale, and of many others labouring in the same direction and in various ways, have shown, what was indeed long suspected, that the solution of the problem of the actual relation between Function and Organ may be sought, and has to be sought, among parts mechanically almost as fine as the Chemical Atom; for we have life, secretion, motion, generation in parts, to our

present means of examination, structureless. Yet, although this may be the case, it would be a great error to suppose that there is not much work yet to be done in the more obvious department of Descriptive Anatomy which chiefly occupied older investigators. Every year seems to show this, from the researches of cultivated Palæontologists and Naturalists in every department: for both in this country and on the two continents additions are being unceasingly made to the stock of knowledge either of objects wholly new, or of objects or parts heretofore incompletely described.

For the purposes of the great scientific question of this age, the Causes of the present order of Life on the Globe, it would seem that the minutest accepted data of biological conclusion may have to be revised under new methods. It is a saying among painters, "that a draughtsman *sees* no more than he *knows*." It is true in the same way in Natural Science, that the real signification of a known fact may be concealed for ages. Of this, Pathology offers many examples. The older naturalists, notwithstanding the great learning of such men as Linnæus and Haller, had comparatively either very simple or hypothetical and incorrect notions of the complexities of living Beings and their constituent parts. Chemistry, the Microscope, and the search for the Origin of Species have, in this century, widened the horizon of biological study in a way not less surprising than does the dawn of day to a traveller, who, having by night ascended some lofty peak, sees gradually unfolding an extent and detail of prospect which he can generally survey, though he cannot hope to verify each detail and visit every nook in the brief time allotted to him for travel. The desire "*rerum cognoscere causas*" urges him even more keenly than to know the things themselves. Thus in Biology, the laws of the genesis of every known organic being have now become as much the object of investigation as was once the nature of the being itself. The existence of definite species or varieties was formerly assumed in an arbitrary manner to be a kind of necessity. The search after the laws which produced those species, and the signification of them, has become as ardent as was once the definition of the specific characters. But it is a far more difficult pursuit, and requires either a very special education, or remarkable natural powers. The difficulty pervades every department of Biology in gross and in detail. Darwin seeks the solution for the whole kingdom of nature. The Histologist, the Pathologist, the Organic Chemist approaches it in the detail of every mechanical texture, and of every organic chemical compound. We are apt to look on the Museum of John Hunter as the most philosophic and extensive exposition of Biological Science in this or any other country. And justly so. Inquiring originally into what is the proper treatment of disease, he asks in order, What is its nature? what its cause? how are the functions disordered? how are they performed in health? by what mechanism? how is this mechanism varied? whence did it originate? But compare with his knowledge the knowledge of biologists of the present period viewed collectively: take our knowledge of the ovum, for instance, and its development, or the minute anatomy of the tissues, or (may I venture to use the epithet for so vast a collection of ascertained truth?) the *nascent* chemistry of living structures, or the relations of osseous structures in the Vertebrata. It were hard to say which is the more remarkable, Hunter's comprehensiveness, or the detail of modern science. Yet how many details are still needed for a safe Biological Philosophy.

Yet are we only on the threshold of detailed knowledge. We still speak of many hard points with an almost childlike simplicity. What do we understand, for instance, of the cause of that which Herbert Spencer calls "*Organic Polarity*"—that is to say, the power, force, or tendency by which lost parts are repaired—by which a whole limb—or part of a limb—or even all but a whole body is replaced by the outgrowth from what remains of the original unmutated whole—a process so common in Asteriadae and Crustacea and other animals as to seem a matter of course in their history, while it is apparently a property which cannot exist in the higher animals? What do we know of the causes of hereditary transmission *in general* (a property wholly different from, and more unintelligible, than the hypothesis of natural selection), or of the transmission of disease *in particular*, as for example, of Carcinoma? What is it in its essence? How does it originate in an individual of untainted family? How is it transmitted? Is it an original

property of the ovum *per se*, or of the nutrient plasma by which that ovum is nourished up to the time of its birth? Could food, or mode of life, or any specific agent eradicate the tendencies to transmission, just as in certain cases we empirically modify the transmission of tubercle? or is the transmission of the Carcinoma as inevitable in certain cases as the development of the germ? Grave questions for future solution.

These allusions to disease, I need not say, are purposely introduced. There seems to be a tendency in some modern physiologists to pay insufficient attention to the retrograde metamorphosis of living creatures. The study of death is as much an object of biological science as the study of birth. The whole being originates, reaches maturity, declines, and dies. So does every part. He strives with vain endeavour to grasp the history of any organic thing, who does not regard it in relation to its origin, its growth, its dissolution, its relations to objects external to it, the changes which it undergoes in itself and of itself, and the modifications, accidental or necessary, which external agents can and may induce in it.

General considerations of this kind have a certain, though subordinate office in scientific deliberations, and seem just now not out of place. It will be remembered that I have been speaking of the intrinsic difficulties of biological study. If I have correctly, though briefly, sketched the domain of Biology, the existence of these difficulties will be conceded. They are now insisted upon, not certainly so much for the sake of those skilled experts, our teachers, who are carrying on the conquest of Nature, as of those many cultivated learners who, from want of leisure, cannot actively pursue, but who, from real interest, desire to aid and promote the study of Biology. For them it is desirable to take from time to time a *general* survey of the aims and extent of Biology, in order that they may bring the weight of their influence in support—1st, of free, unfettered pursuit of Biology for its own sake; and 2ndly, of public education, such as may conduce in the next generation to a just appreciation of its scientific, its educational, and its practical value.

I am thus led to consider, 2ndly, the Prejudices of Mankind, "*opiniones præjudicatæ*," in respect of Biology.

These resolve themselves into Active Prejudices and Passive Prejudices. *Active* lead men to object to it as harmful; *Passive* lead them to regard it with indifference.

These prejudices are rapidly undergoing modification, but they have existed harmfully more or less, from various causes, among almost all but professed Physiologists. I need only advert among the *Active* prejudices to the so-called theological dread of free inquiry into the origin of Races, and the origin of Species generally. Among the *Passive* prejudices, I would point to the want of appreciation of purely scientific inquiry that has no practical end in view; to objections of various kinds brought against experiments made for Physiological, Toxicological or Therapeutical purposes; to objections to the introduction of Biological studies into courses of general education; to the tardy recognition of Biological knowledge as the basis of practical Medicine, and of Hygiene, public and private.

History gives the clue to the source of these prejudices, namely, the empirical assumptions of supposed truths made at former, and often ancient epochs, which have one by one to be eradicated from their respective departments before the advancing knowledge of ascertained Natural Law.

What we see around us in the natural world is admitted on all sides to be the result of the operations of causes working by fixed laws. Why those laws exist, or how they came to be, it is not within the domain of Physical Science to discuss. What (in so far as they affect living beings) they are, and what the mode and limit of their action, including (of course) the mode and limits of their possible modification, is the special province of Biological Science. Science therefore is not only at liberty, but is bound, at all times to test the correctness of opinions which bear on or have relations to the subject matter of science, and do not appear to have been founded on adequate scientific evidence. A great part of the scientific work in the present century has been that of recasting or rejecting received dogmas. This work is not yet complete, and possibly never will be. It is evident that new means of research show the incorrectness of the belief of many of the greatest minds. Plato

was satisfied that the use of the Liver was to be the seat of prophetic agency for the soul. Yet are we sure that, notwithstanding the researches of Bernard, Pavy, and others, we know even at this moment all the functions and uses of that organ? How long since is it that taurine was found to contain 25 per cent. of sulphur, and was not, as had been supposed, devoid of that substance? How complicated are the chemical questions of the hepatic functions, when viewed as a whole throughout the animal series, may be seen by a glance at M. Milne-Edwards's summary of these questions in his elaborate work now in course of publication.

The utmost toleration is required in dealing with the prejudices which we are considering: among other reasons, because truly there may be scientific prejudices as well as popular prejudices. A scientific man may become impatient of every opinion which rests only on probability; whereas some of the important issues of human affairs are not susceptible of absolute proof. A physician or a lawyer, or a moralist, who always refused to act on the greater probability would be a sorry adviser to his client. But the work of the chemist or the physiologist would be at once set aside if probability and not ascertained fact entered into his formula.

Different subject matters are taught or studied with different degrees of certainty, or by different methods; the methods and degrees of certainty must be known and acknowledged. There can be no just ground of objection to conclusions based on hypothesis so long as the promoters are ready to accept, on proper and reasonable evidence, new elements of calculation.

I spoke also of the Passive prejudices of mankind in respect of Biology. A curious chapter might be written on the slowness with which physiological principles have been generally received (I cannot say they are even now accepted by us) as the basis on which to secure public and private health. England is but even now awakening to these questions. The Registrar-General, the Army and Navy Departments, the Health Department of the Privy Council, the various Drainage Commissioners and Committees, and many other bodies are all engaged in collecting, disseminating, and in using physiological knowledge under various aspects. It must be admitted that evidence as to what is and what is not favourable to the correct performance of the functions in men and other animals is even now often conflicting. It was said just now that the pure Physiologist is too apt to disregard the processes "*præparantes ad mortem*;" so also he is too apt to look on Health Questions as problems of Practice or Art, and not of Science. Yet the highest scientific qualities are requisite for determining with precision any problems affecting, for instance, Nutrition, and the consequent Capacity for labour of a population, viewed as a whole or as individuals: witness the investigations of your last year's President (now, happily, employed by the Government), and many of the important papers in Mr. Simon's valuable yearly Reports, and such memoirs as that of Professor Haughton of Dublin on *Work*. In such cases, I will not say *Theory*, but knowledge precedes, and regulates, and compels practice.

Similar considerations apply to the relation of Physiology to Practical Medicine. This art or science is undergoing revision under the influence of Physiology, a revision somewhat indeed retarded by popular prejudice, but certain.

In looking back on the history of medicine we are at a loss to say which is the more curious, the sagacity of the older physicians and surgeons, considering the scantiness of their physiological knowledge, or their folly, considering the extent of it. The explanation lies in the intermixture of empirical (that is, of accepted, traditional, unquestioned) belief with really ascertained fact; and we are not now-a-days without danger of undervaluing the eminent artistic power and great practical shrewdness of former physicians, in the presence of our more precise, but sometimes also less practically valuable scientific knowledge. Dr. Stokes, the eminent Dublin Professor, has lately spoken on this topic in a timely and earnest way.

The business of Physiology and of an Association like this, as I just now said, is therefore not only to add new knowledge, but to destroy incorrect or imperfectly correct statement and belief. The incorporation of advancing Physiology with Medicine every year adds certainty to the latter, while it furnishes data as well as tests to the former. Experiment properly applied in Medicine under trained physicians and

chemists will not only eliminate gradually all remaining error, but will make more definite the properties of therapeutical agents. In illustration it is sufficient to refer to some of the investigations of Claude Bernard, from whose great skill, combined with philosophic power, much may be expected. Yet it may be doubted if the importance of this alliance between Science and Medicine to the community at large is yet fully understood by the Legislature. Under the recent Medical Act, the whole expense of constructing a National Pharmacopœia was thrown by Parliament on the existing Practitioners of Medicine, and the cost of its future maintenance was charged on the Students of Medicine: the national funds are to contribute nothing towards the great benefit, a benefit accruing to every one at some period of life, of a genuine and philosophical revision of known, or the discovery of new, curative agents. Experiment alone can decide conclusively on the mode of operation of various agents on the human body and on animals. These experiments are always difficult, often costly. The Government, as I said, do not acknowledge the duty of providing funds. Perhaps the Medical Council might. It is indeed charged with the administration of the only Public Funds that are applicable to keeping on a level with modern science the National Catalogue of Remedial Agents and the mode of preparing them. If it could be induced to expend £1000 a year, as under proper management it easily might, in experiments and reports bearing on the physiological action of preventive or remedial agents, sometimes perhaps suggested and aided by the British Association, what might not be the fruit to science and to the public and private health?

I have been assuming, what no one here will question, that the basis of Medicine is knowledge of biological laws. It is so, but only in the wide sense assigned at the outset to biological pursuits; viz. the study of the laws of decay as well as of growth—growth and decay of species as well as of individuals. But I must guard myself by saying that this does not include the whole basis of medicine. Physiological experiment is necessary to obtain the laws of action on healthy bodies, but alone it does not explain the laws of action on perverted organic structures or functions, as is seen in the common instance of the different effect of opium on a man in health and on a man in disease. Clinical observation is of course beyond physiological research, and must, from its far more limited field, follow rather than precede. It aims at applying, in due course, all safe and established results of previous physiological inquiry; and adds the deductions from investigations exclusively its own.

Much remains to be done in comparing the effects of agents, and the causes of those effects on man and on the inferior animals respectively. The knowledge which exists on these subjects has become, I need not say, both extensive and precise. But new problems are constantly arising from the discovery of new Toxic agents. Even new diseases occur, as is well instanced by Cholera, implying either new conditions of circumstances external to man, or new combinations of the internal conditions of man.

Accordingly fresh experiments are perpetually required to meet the new problems; and it has become the interest and almost the duty of States to specially train and to countenance skilled experts familiar with the most recent methods and researches in these directions, with a view not only to fresh scientific knowledge, but to the great practical results that may be obtained. It is sufficient to refer as illustrations to Bernard's experiments, such as those on the Woorara—to the question of Physiological Antidotes—and to the more precise notions of the Physiological causation and mode of action of Fever Poison.

These you will observe, though apparently what are called medical questions, are not less physiological questions proper, of vast importance to mankind.

A few more words in another aspect, and I will not venture further to trouble the Section, or delay our detailed work, which is ample enough. I have implied, what is sufficiently obvious, that Physiology proper (I exclude such questions as the evolution hypothesis, which cannot be proved in this way) has become uncompromisingly precise, and that nothing will stand which does not bear the crucial tests of observation, and where possible of *experiment*. But the experiments cannot in the present advanced state of Physics and of Chemistry be devised by ordinary men, nor even executed by them. Consequently every year old statements

concerning the effects of agents so called Physiological and Therapeutical, are becoming of less value, and new ones of more. Most of us, who have passed the prime of life, must be content to learn from the more favoured in years. They who are young must be willing to be patient and laborious, if they would add any thing of permanent value to physiological knowledge. The day in which hundreds of organic compounds are synthetically produced, and the microscope offers for mechanical analysis a clearly defining magnifying power of 5000 linear, is not one when rough work of hand, or conjecture unsupported by proof as to the chemical changes which go on within organic structures, will stand. What Life is will long, perhaps always evade our human ken; what is done during Life, what can be done consistently with Life, and what produces death among living things, every year makes more sure and more plain; every year makes the search more exciting, the reward more great, the reasons for admiration of the order of things on the whole more conclusive, and the admiration and awe more profound.

At the outset it was said that only very qualified assent could be given to the remark of a philosophical writer, that it is a prime necessity for Biology that it should be separated from Medicine. It has been my endeavour to show the amount of truth which belongs respectively to the remark and to the dissent.

Physiology, to sum up, is become a science, precise, of enormous extent, bringing to its support mathematics, advanced physics, difficult chemistry, accurate and comprehensive anatomy. Part of the basis of the science or art, which averts or lessens suffering and disease, and postpones or makes easy death, depends in great measure upon its progress. But the applied and observational part can only be learned by the bed-side of the sick. Therefore pure Biological Science and pure Clinical Art must each have their votaries, but it must be the aim of each to learn from the other what is necessary for himself. May the State be wise enough (and it is becoming so in every civilized country) to appreciate these principles and their application! There never was an age—it is not ungrateful to the giants of old to say this—there never was an age when there were so many students, in the best sense, of Biology and of Medicine, actuated by a simple love of truth; and never a time when, as a class, they were so free from prejudice, so candid, and so patient.

On Life. By Dr. LIONEL S. BEALE, F.R.S.

On the Formation of Pus, in reference to the doctrine of Cell Pathology. By J. HUGHES BENNETT, M.D., Professor of the Institutes of Medicine, &c. in the University of Edinburgh.

Dr. Bennett stated that a cell pathology had naturally sprung from the cell theory as originally framed by its founders, Schleiden and Schwann, which had greatly extended the boundaries of science. The cell pathology of Virchow, however, was based upon a law he sought to establish, viz., that every cell sprung from a pre-existing cell, and that we must not transfer the seat of real action to any point beyond the cell. This supposed law, the author maintained, was opposed by so many histological facts as to be altogether untenable. He begged especially to draw attention to the origin of pus-cells, which Virchow and some of his followers had represented as originating in the interior of connective-tissue corpuscles. Dr. Bennett and his pupils had frequently sought, by passing setons through the skin and muscles of animals, to observe in the inflamed tissues the appearances which had been figured in support of Virchow's views, but had never succeeded in seeing pus-cells within preexisting cells. Henle had pointed out that the error had originated in mistaking the triangular spaces observable on a transverse section between the bundles of various fibrous tissues for cells, as in these unquestionably pus was very likely to collect. Dr. Bennett further believed that the tendency of many cells to enlarge as the result of irritation, and to multiply themselves endogenously, as shown by himself, Lebert, Goodsir, Redfern, and other pathologists, was another source of mistake among the younger histologists. The granules and included cells so formed were mistaken by them for those of pus, though easily separated from them. He called attention to a series of preparations (which were exhibited) showing suppuration in inflamed eyeballs and in pneumonic lungs, in which pus-

cells might be seen in all stages of formation, originating from a coagulated molecular exudation, unconnected with any preexisting cells whatever. In the sections of pneumonic lung more especially, the fibrous tissues of the organ might be seen to be quite healthy. In the coagulated exudation, on the other hand, the molecules might be observed at first uniformly filling up the air-vesicle, then formed into masses varying in size from the twenty-thousandth to the one-thousandth of an inch in diameter. The latter were rounded, and were identical with pus-cells. He believed that these bodies, therefore, were formed by an aggregation of smaller particles or molecules, comprised originally of the coagulated exudation. It was certain that in the situations referred to they did not originate in preexisting cells, as no such cells could be observed. If, as might be supposed, they sprung from the epithelial cells lining the chambers of the eye or the air-vesicles, such cells would be seen enlarged and containing the pus bodies. But his preparations and numerous examinations of the parts when diseased had proved to him that no such cells were mingled with the exudation, or were in any way connected with the formation of pus. These facts were wholly subversive of the law of cell pathology sought to be established by Virchow.

On Beef and Pork as Sources of Entozoa. By Dr. COBBOLD, F.R.S.

The paper commenced by showing that much misunderstanding prevailed, even amongst eminent authorities, as to the most frequent source of human cestode entozoa. The author combated the notion so commonly entertained that pork was the chief source of human tapeworms, and, in proof, referred to the results of his original experiments, as well as to data supplied by other means. He showed that the unarmed tapeworm (*Tania mediocanellata*) was more abundant in this country than the hooked tapeworm (*Tenia solium*), which latter species, however, was somewhat more prevalent in Birmingham than the same species elsewhere. He threw out several hints respecting the primary origin of these and other human parasites, and contended that the human body was the legitimate home and territory of some of these parasites. They did not, and probably could not reside in any other creature in their adult state. In the case of *Trichina*, it was by no means certain that the pig constituted the primary host. The original "creative centre" was possibly antecedent to the race of swine.

Remarks on Specimens of Entozoa. By Dr. COBBOLD, F.R.S.

The author exhibited six preparations, being part of an extensive series which he recently made for the Museum of the Royal College of Surgeons, London. Particular attention was drawn, in the first instance, to a specimen of *Trichina spiralis*. This parasite was shown, in the encysted condition, in a portion of the great pectoral muscle of a dissecting-room subject. The author had fed various animals with this trichinized flesh, and had reared in them a numerous offspring. Next, in point of importance, was a portion of muscle from a calf, in which animal Dr. Cobbold had succeeded in rearing numerous "measles" (*Cysticercus bovis*, T. S. C.) by the administration of the proglottides of the unarmed human tapeworm (*Tania mediocanellata*). He also showed measles (*Cyst. cellulose*) from the pig, and several hydatids furnished with Echinococcus-brood-capsules. He expressed his thanks to the Association for the funds which had been allotted for the purpose of carrying on these experimental investigations.

On the Effects of Scanty and Deficient Diet. By JOHN DAVY, M.D., F.R.S., &c.

It seems to be now laid down as a rule or principle that the health and constitution of man must suffer permanently if for any length of time he has not a full allowance of food, *i. e.* a quantity adequate to preserve him in an average state of health and strength. And on this principle the formation of dietaries for the inmates of all public institutions, whether workhouses or prisons, has been more or less strictly founded.*

Is this principle, or, as it might be called, postulate, well established and supported by facts?

The following are some of the circumstances which have given rise in the author's mind to doubt:—

1st, then, taking the instance of the adult man: is there any evidence that those engaged in expeditions or services in which for a period the allowance of food was deficient, though they were weakened indeed greatly at the time, experienced any permanently bad effects? Those who belonged to the arctic exploring parties, whether by sea or land, have not eventually suffered. The author referred specially to the cases of the late Sir John Richardson, who had suffered so much from privation in his first arctic journey, and his companion, the late Sir John Franklin. They were reduced by starvation to such a state that even their minds were enfeebled; and when they arrived at a station where their wants could be supplied, they were intent on nothing but cooking and eating, day and night. Nor is there evidence that any African traveller, whatever his privations, if so fortunate as to return to this country, suffered eventually. The late Captain Speke is an instance in point, and both of the effects of deficient diet with fatigue and of ample diet with rest. Captain Burton, his companion, a traveller in so many lands, and of such vast experience as a traveller, affords evidence in his own person corroborative of the fact that temporary privation is not necessarily permanently injurious; indeed he expresses it as his opinion that occasional fasting is beneficial.

2. A deficiency of food, especially of fresh vegetables, is productive, as is well known, of scurvy, accompanied by a diseased state of the blood and great loss of bodily strength; yet how soon does recovery take place when a wholesome invigorating diet is supplied. Nor is the author aware that scurvy is productive of any taint, as a sequela, injurious to the constitution. And he apprehends that the same remark is applicable in relation to consequences, to all acute diseases, such as are not accompanied by organic lesions of a permanent kind. It is marvellous, in cases of recovery from yellow fever and some other fevers, how rapid is the convalescence, the gain of weight, and the restoration of vigour.

3. Taking the instances of tribes of people: some are scantily fed, or, at least, owing to the regions they inhabit and their habits as to their mode of procuring food, are often for a considerable time on a scant allowance, sometimes approaching the starvation degree. Such races are the Boshmen of Southern Africa, the Tasmanians, the aborigines of Australia, the Veddahs of Ceylon, who all lead the precarious life adverted to as to diet, depending chiefly for their daily food for their success in the chase. What is their condition? All of them are below the average in height and size and are thin in person; but they are not said to be unhealthy races, or subject to any special diseases attributable to their mode of life.

4. Taking examples of different ages—the young during the period of growth, adults, the middle-aged, the advanced in years, and the very aged—in either of these stages have we proof that there is any disease special to either when too sparingly fed, provided the food they have is of a wholesome kind? During the period of distress in Lancashire, owing to the diminished imports of cotton, it would appear that the people generally were in tolerable health; indeed it is stated that they were in improved health, and that there was actually a diminished rate of mortality. Yet we may be sure that, during that calamitous time, a very large number of men, women, and children must have been underfed. Of the men and women most remarkable for longevity, the greater number have been of the labouring class—individuals of whom it may be pretty confidently asserted that their diet was sparse rather than abundant. Though the Irish, as a people, owing to their dependancy on the potato, have been greater sufferers from famine than the English in modern times, yet it is remarkable that the number of persons in that country who have attained the age of 90 years is greater than in England, with a population, comparing the two, so greatly in excess.

5. Taking instances of peoples and persons well fed and regularly so, in what particulars do they differ chiefly from the preceding? Pastoral and agricultural tribes well to do may be cited as examples—such as the Caffres of Southern Africa, living chiefly on milk; and, amongst Europeans, the middle-class, using a mixed diet, and that without stint. Such—and the Caffres and our own countrymen are striking examples—are chiefly remarkable for a size exceeding the average of mankind, and for a full development with proportional strength and energy; but the author is

not aware that they are more exempt from diseases, especially of the chronic, cachectic kind, than those of a smaller size and more spare habit.

6. Brute animals afford analogies. The fell sheep of the north of England and of Wales, picking up a scanty subsistence on the poor pastures of the mountain sides, are equally remarkable for their hardihood, activity, small size, and the goodness of the mutton they afford. A like remark is applicable to the cattle of similar districts, such as the Highlands of Scotland and the wilder parts of Ireland and Wales—how inferior are they in size to the longhorns of Devon and the shorthorns of Herefordshire, feeding in rich meadows! The horse is another instance. Wherever the pasture is poor, ponies will be found; but though small, they are nowise deficient in strength, activity, and power of endurance. Large horses are the product of rich pastures and an unfailing supply of nutritious food. The Yorkshire breeder, to secure horses most in request, as rated by size and muscle, allows the colt the milk of two mares. And we are told that in some of the Polynesian islands the sons of chiefs are similarly reared, so as to secure a princely bulk and stature.

7. If, then, it be not proved that a scanty or somewhat scanty diet is not permanently injurious to man, is it right that men undergoing imprisonment for crime should be otherwise than sparingly fed? Should the allowance in the least exceed that sufficient to keep the criminal in a state of health and strength somewhat below par, and merely adequate to that moderate degree of labour erroneously designated “hard labour” to which he may be sentenced? What is the general state of health of such prisoners at present in the county jails, where the dietaries are least in excess? So far as the author had been able to learn, disease amongst them is in less proportion than in the general population of the country, and the mortality less.

The advocates for a liberal diet for prisoners hold that, under the depressing influence of such confinement, more food is required to prevent undue waste and to preserve vigour. This seems a very questionable doctrine. Mental depression impairs the appetite; and without an appetite for food, little, it may be expected, will be digested and assimilated. Were the doctrine sound, and to be carried out in the instance of prisoners, should they not be allowed stimulants—wine and beer?

On the principle, indeed, of not endangering health, ought not imprisonment for crime to be abolished altogether? for, according to the advocates of a more liberal diet, the confinement, with the opprobrium attached to it, operates on the mind, depresses the spirits, and is thus injurious to health.

Those who expect effects deleterious to the constitution, productive of cachectic diseases, and especially pulmonary consumption, from a spare diet, refer to poor needlewomen and nuns, amongst whom this disease is especially prevalent. But in their cases other causes are in operation; and in the instances of the former almost every cause likely to undermine the constitution—poor as well as scanty food—bad lodgings, ill ventilated—overwork—privation of open-air exercise—and, not least, the want of mental exhilaration; and they are commonly of a class with sensitive minds: and the circumstances acting on nuns are often in many respects similar.

The author contended that it was a false humanity to allow a high rate of diet to prisoners, with the intent of supporting them in their full working strength (thus making a prison life *quoad* diet as little irksome as possible, and so far detracting from the idea of punishment) and, on discharge in full vigour, the better able to renew their criminal courses.

The principle of a full diet for prisoners is not well established as essentially necessary. There should be, he urged, further inquiry instituted to determine the dietary limits, the lowest not seriously endangering a permanent injury of the constitution.

Is the Opinion that a Diet of Animal Food conduces to Leanness well founded on Facts? By JOHN DAVY, M.D., F.R.S., &c.

Those who have advocated this opinion, viz. that a diet of animal food conduces to leanness, have supported it by two trains of argument,—one, that a vegetable diet

is richer commonly in the elements from which adipose matter can be formed, such as starch, &c., than flesh; the other, that carnivorous animals are commonly leaner than herbivorous, the food of which is entirely vegetable.

The strength of the first argument it is not easy to appreciate, inasmuch as certain kinds of animal food abound in fatty matter; it is therefore passed by.

The second train of argument is more important, and is more easily tested as to accuracy. Now if it be true that an animal diet conduces to leanness, and this as a rule, it should bear the strictest scrutiny; we should find it confirmed by facts of an unquestionable kind, *i.e.* by exact observations free, as much as possible, from any fallacy. The following are some which appear to lay claim to be so considered.

1. The nestling of the swallow fed entirely on insects, when fully fledged and capable of taking flight, is found by the author to be heavier than the parent bird, and this owing to its being fatter; and it is found also that it loses weight after leaving its nest and taking exercise on the wing, and this in consequence of a diminution of its fat.

2. The buzzard, like its congeners of the falcon family, subsists entirely on animal food, chiefly small birds; it, according to the argument, should be lean; but the author has not found it so. One, a female, examined in January, killed in the Lake District, and in full vigour, was found loaded with fat. The bird weighed about two pounds; the fat that was separable, consisting chiefly of stearine, weighed six ounces and a half; and besides this, there was a considerable quantity remaining, not easily detachable from the muscles, &c. The lard-like fat was found externally covering a large portion of the thorax and the whole of the abdomen, and internally lining the sternum and the abdominal contents, especially the stomach and intestines.

3. Many years ago, when in Ceylon, the author had the opportunity of dissecting a full-grown Chetah (*Felis pardus*); he found it not merely in good condition, but more than that, abounding in fat; its mesentery had deposited on it a thick layer of fat.

4. Fishes, those of which the food is entirely animal matter, are many of them remarkable not for leanness, but for their fatness. Very many instances might be mentioned; two may suffice. The salmon, on its ascent from the sea, after luxurious feeding there; and the eel, on its descent from fresh water to salt—both fishes actuated by a similar instinct, that of spawning, seeking water of opposite qualities, are then in their highest condition, and abounding in fat; on the contrary, when returning, one to the sea, the other to the rivers after spawning, are remarkable for being wasted and lean; this, from the loss of fat, the consequence of a long comparative fast.

These, the author hoped, may be received as verified facts, tending strongly to show that a diet exclusively of animal food is no wise incompatible with fatness.

5. If we refer to our own species, it is easy to find corroborative instances. Butchers and their families, who use a large proportion of meat, are surely not remarkable for leanness. The same remark applies to fishermen and their families, who use fish largely at their meals. The English, as a people, have always been considered large consumers of meat, and especially in the olden time, when vegetables were less abundant than at present. Père Labat, who wrote his account of the West India Islands towards the middle of the last century, states, when giving an account of the Caribs, whom he describes as Cannibals, that he was assured by them that they could distinguish an Englishman from any other race of men, and that at their feasts they gave him the preference, on account of the meals he yielded being richer and more juicy. Shakspeare, who of all poets surpassed in accuracy of observation, had he believed that a meat diet conduced to leanness, would never have depicted his fat knight, Sir John Falstaff, who speaks of himself apologetically as "having more flesh than another man, and therefore more frailty," as one so addicted to capons and sack.

6. Did a vegetable diet favour the production of fat, the Irish, living mostly on the potato, should be distinguished for lustiness, which they certainly are not. Vegetarians should especially be so distinguished; but the author never heard it asserted that such a distinction belongs to them.

A fallacy lurks under the idea that an animal diet and a spare habit of body are associated, partly owing to the circumstance that races of men who use this diet—such as those who are dependent on the chase for a subsistence—are compelled to take much exercise in the pursuit of game, and are often, from scarcity of game, underfed. Nearly the same remark is applicable to our soldiers and sailors, amongst whom a fat man is a rarity; and no wonder, as though their diet contains a large proportion of animal matter, their meat ration is never in excess; they are rather, especially the soldiers hitherto, underfed than overfed; and want of exercise surely is not one of their wants.

In conclusion, should the facts here brought forward be considered not altogether conclusive in proof that an animal diet is not specially favourable to a spare habit of body, they may at least suffice to render the opinion doubtful as to its accuracy.

The author's belief is, and it seems to be the received opinion of most physiologists—one the best founded in experience and most in accordance with the structure of man, and the organs chiefly concerned in digestion,—that a mixed diet, partly animal, partly vegetable, is best adapted to his wants, as well as most suitable and pleasing to his taste; and that the safest way to prevent obesity is to live moderately, observing the happy medium between a too sparing and a too copious dietary; and for the correction of obesity, attending to quantity rather than to quality of food.

As a striking example of what may be accomplished in the reduction of corpulency, a few particulars were added of a man, Thomas Hood, of whom an account has been given by Sir George Baker in the 'Medical Transactions' for 1767.

The author also referred to the case of Cornaro, who attained his 101 year, and from his fortieth year restricted himself to 12 ozs. of solid food and to 14 ozs. of wine, and this with the best effects; for from a suffering invalid he became a healthy man, and continued in the enjoyment of excellent health without interruption to the end of his long life.

On the Functions of the Cerebellum. By Dr. W. DICKENSON.

On the Prevalence of Tapeworm in Birmingham, and its Causes.
By Dr. FLEMING.

The author stated that tapeworm prevailed to a great extent in Birmingham, and was often to be seen in its severest forms among the patients of its several hospitals. As compared with Edinburgh, the greater frequency of the disease in Birmingham is very marked. In the General Hospital, the entire number of in- and out-patients, in the year ending June 30, 1864, was 22,649, and of these there were 51 cases of tapeworm; in the Queen's Hospital, the number of patients during the same period was 11,376, and of these 75 were cases of tapeworm; and in the General Dispensary the number of patients was 4516, there being 12 cases of tapeworm. In Edinburgh, the proportion of tapeworm cases in the hospitals was very small.

The author, having explained how the measles in the pig developed into tapeworms in man, attributed its prevalence in Birmingham to the large consumption of pork, which in this town is a favourite article of food.

The average number of pigs sold in Birmingham market weekly is 1500, and of these two-thirds come from Ireland, where the hog suffers more from measles than in any other part of the kingdom. In spite of the careful inspection of the markets, there is little doubt that a considerable quantity of the pork sold is measly. When affected by the disease to such an extent as to render its exposure for public sale hazardous, it is disposed of privately, and much of it is used in making sausages.

With regard to the prevention of tapeworm, Dr. Fleming urged that the official inspection of living and dead pigs should be made as searching as possible; but as this will not suffice completely to protect the public, he advises that information on the subject should be widely diffused, and thus make each consumer his own inspector. Further, all pork should be eaten either thoroughly well cooked or thoroughly well cured, both of which processes destroy the parasite. The use of other than home-made sausages should be strictly avoided.

On Experiments confirmatory of those of Kühne on the Non-existence of Ammonia in Blood. By Dr. A. GAMGEE.

The author referred to the conclusions which Dr. Richardson had arrived at, 1st, that the blood, whilst circulating in the living body, contained free ammonia; 2nd, that when the blood leaves the animal body, ammonia escapes and coagulation takes place, the escape of the ammonia and the phenomenon of coagulation being considered to stand in the relation of cause and effect. The author had made some experiments which were in direct opposition to those of so distinguished an experimenter as Dr. Richardson; and as the quantity of blood which Kühne and Strauch subjected to analysis was comparatively small, he had determined on repeating the experiments in the most rigid manner possible, and upon a larger scale than had been previously attempted. The experiments consisted in introducing blood taken from the carotids of living animals directly into an atmosphere of pure hydrogen, and allowing hydrogen to bubble through the fluid. The gases thus expelled were conducted into Nessler's reagent. This (the most delicate test for ammonia) failed in detecting the faintest trace of free ammonia, although it was proved to be capable of detecting 0.56 gr. of ammonia when mixed with 140 ozs. of blood, and 20 ozs. of water.

The author then discussed the question as to whether the blood contained one of the compound ammonias, instead of ordinary ammonia. He stated that all the compound ammonias which he had examined gave reaction with Nessler's reagent, and the author concluded by remarking that further researches would, he believed, confirm the results of the experiments which he had performed, and satisfactorily prove that Nessler's reagent was as delicate a test for the compound ammonias as for simple ammonia.

Refutation of the View recently propounded that the Food comes into contact with the Vocal Cords in Deglutition. By GEORGE DUNCAN GIBB, M.A., M.D., LL.D., F.G.S.

The author referred to the recent experiments of M. Guinier, of Montpellier, in relation to the function of deglutition, which were brought before the Academy of Sciences in Paris, and given briefly in the 'Comptes Rendus' for May last. These experiments by M. Guinier were performed upon himself by means of autolaryngoscopy, and consisted in the introduction of food into the larynx whilst the little mirror was in the mouth, the epiglottis remaining erect; and he therefore inferred that, in swallowing, the food passed into the top of the windpipe, glided over the vocal cords, and tumbled into the gullet, the epiglottis still being erect. He inferred also that fluids always passed under the epiglottis in gargling or swallowing fluids. Dr. Gibb questioned the conclusions drawn from the experiments, and maintained that the act of swallowing food could not be demonstrated with a mirror at the back of the mouth, and that the introduction of food into the larynx behind the epiglottis showed the tolerance of the larynx under certain circumstances, but did not show that this cartilage remained erect in deglutition. This tolerance was further shown by the still later experiments of M. Krishaber, who passed chewed bread into the larynx with his finger, along the posterior surface of the epiglottis, and on a deep inspiration this was drawn downwards into the trachea, and could be retained there as long as the bolus remained warm and soft. Dr. Gibb referred to cases in his own experience, where the epiglottis was destroyed by disease, and, notwithstanding, the food did not glide over the vocal cords, as the soft parts at the top of the windpipe approximated and allowed the food to slip into the gullet. It could be seen also, that when the act of deglutition was examined with the laryngoscope, the cavity of the larynx was quite closed up, and then covered by the depressed epiglottis, so that food could not enter in the natural way. From these well-known facts, with others which he mentioned, Dr. Gibb stated that our well-known views in relation to deglutition, and the part the epiglottis played in it, remained sound, and could not be controverted by any experiments that might be made with the aid of the laryngoscope.

Remarks on the Skeleton of a Woman æt. 104. By Dr. G. M. HUMPHRY, F.R.S.

The woman had been a temperate person, eating rather heartily and drinking

about half a pint of beer daily. Describing the *post-mortem* appearances, Dr. H. said the organs were all sound and healthy, and the cause of death was accumulation in the bronchial tubes. The costal cartilages were as soft as in early life. The same thing was noticed in the *post-mortem* examination of old Parr by Dr. Harvey, and this was thought by him and by subsequent writers to be a condition peculiar to old Parr, but he, Dr. Humphry, had met with the same in many examinations of aged people. It is well known that after the middle period of life the costal cartilages often lose their elasticity, and become more or less calcified. Dr. Humphry is inclined to regard this change as not so much an attendant upon age as upon an unhealthy condition of the system. He considers it, in short, to be a morbid rather than a senile change, and intimated that some aid to prognosis respecting longevity might be furnished by an examination of the walls of the chest, a deficiency in their elasticity being an indication of commencing failure of the nutritive functions. The walls of the skull were unusually thick and heavy, the skull weighing $27\frac{1}{2}$ ounces, or at least six ounces more than the average of adult skulls. In singular contrast with the condition of the skull was the state of the femur, which was fragile, porous, and light, weighing only five ounces. Dr. Humphry pointed out this as an anomaly, that when the muscles and bones of the body generally had become weak and less able to carry weight, the weight to be carried should be increased by the increased thickness and heaviness of the skull. The only other change noticed by Dr. Humphry was the depression of the head of the femur, the angle formed by the neck with the shaft being only 100° . He had often found it as low as 110° in old persons. In the adult it is usually from 125° to 130° .

On the Vascular Arrangements of the Cornea. By Dr. W. H. LIGHTBODY.

In this paper the cornea was shown to be non-vascular, except at its extreme margin, even during fetal life, the capillaries ending in loops. The circular venous sinus of Schlemm was described as occurring about the middle thickness of the junction of the cornea and sclerotic, not at the point of division of the posterior elastic lamina, where it usually is said to be. Certain very delicate membranous sheaths were described, surrounding the capillaries of the cornea of many if not of all animals, in some, as the sheep, containing, in addition to the blood-vessel, corpuscles identical in appearance with lymph-corpuscles: also large trunks, not containing blood-vessels, but having the corpuscles in them, were shown leading from the cornea into the sclerotic. The opinion was put forth that these sheaths and trunks are really lymphatics, and it was supported by the recently-published discovery of Professor His, viz., that the vessels of the brain and spinal cord are surrounded by sheaths capable of being injected, and from which the lymphatics of the membranes of these organs may also be injected.

On the Development of the Vascular System of the Fœtus in the Vertebrata, with the view to determine the true course of the Circulation through the Veins and Arteries of the Human Fœtus in utero. By Prof. MACDONALD.

The early stages of embryonic or foetal development have long been well exhibited by the phenomena of the incubated egg of the domestic poultry; on the present occasion the same field will be referred to in tracing the growth of the vascular system.

Having shown that the rudimentary heart of the embryo is formed by bending a tube in the vascular area between the serous and mucous layer, it first appears as a sacculated cone lying in front of the head of the embryo. From the lower part, on the right side, a vein protrudes passing upwards to the sinus terminalis, from which the blood filtrates through the capillary area of the blastoderm, forming the blastoderm arteries which enter the embryo, pouring the aërated blood on each side into aortæ. The aorta on each side of the chorda centralis terminates in four branches; 1st, to the heart for its growth; 2nd, to the submaxillary region for the growth of the lungs, and possibly the subelavian; 3rd, the external carotid and facial arteries; and 4th, the terminal or internal carotid for the development of the brain. The blood then returns to the atrium cordis by the two veins which enter on the left side. After the ovule arrives at the uterus, the flocculi of the shaggy

external chorion form the placenta by the umbilical vein pouring its blood among the non-vascular branches of the shaggy chorion, as in the earlier stage of the blastoderm capillary area; from this the umbilical arteries receive the arterial blood to be sent by the cord to the foetus for distribution through the body. The heart of the foetus still continues for some time a unilocular cavity. The ventricle gradually grows outside of the atrium cordis, and for some time it continues as a single cavity. The atrium cordis soon becomes divided into the right and left auricles.

The ventricle in like manner becomes divided by a septum separating the right and left ventricles. The aortic bulb may assist the circulation. The circulation thus begun by the venous blood being sent by the umbilical vein to the placenta, when the heart consisted of a single cavity, the blood would only return by the arteries of the cord to the aorta through the umbilicus, and thus the course of the circulation in the foetus as usually described is, according to the author, erroneous.

Rigor Mortis not Muscular Contraction. By Dr. R. NORRIS.

The commonly received theory of rigor mortis is, that it is an energetic muscular contraction. That this view is erroneous is proved by the following considerations:—1st. That the rigor of opposing sets of muscles does not cause the redispotion of limbs in obedience to the superior powers of the stronger sets of opponents. 2nd. That if either the flexors or extensors of a limb be divided and the limb be placed, before rigor has set in, in the position in which it should be drawn by the cut set of muscles had the action of these been unopposed, the uncut set of muscles do not alter that position. 3rd. Contraction and the presence of irritability being an inseparable association, it follows that if irritability be absent for a long time immediately prior to the supervention of rigor mortis, the latter cannot be regarded as a contraction. 4th. The microscopical appearance of muscular tissue affected with rigor mortis is entirely different from that of muscular tissue in a state of contraction. The truth of these arguments he had demonstrated by a variety of experiments, selections from which were set forth in detail. Photographs of many of the results and specimens of others were submitted to the Section. Rigor mortis is therefore not a contraction, either energetic or otherwise, of muscular tissue. It is a suspension of the property of extensibility, probably due to a solidification (coagulation?) of a fibrinous (?) material contained in the interfibrillar juices of the muscles, as asserted by Brücke and Kühne, the resolution of which by incipient decomposition restores to the muscles their mobility.

On the Early Development of Organs in Embryonic Life.

By SAMUEL H. PARKES.

The difficulty of demonstrating the general anatomy of animals at a very early period of gestation may be greatly lessened by hardening the foetus in alcohol, and then making a consecutive series of very thin sections.

A number of such preparations were exhibited, viz., foetal rat at twenty-first day of gestation; foetal rabbit at twenty-fourth day; foetal calf, two months; foetal dog, two months; human foetus, two months; and bantam chick artificially hatched. In these preparations may be seen the whole of the internal organs *in situ*, each section showing the correct relative position of organs lying in the plane of such section.

The advanced state of development which exists at this early period in the structural peculiarities of the visceral organs is truly astonishing. In the sections of a human foetus (of about two months), for instance, may be seen at one view some of the distinctive characteristics of cuticle, muscle, bone, spinal cord, heart, lungs, liver, kidney with suprarenal capsules, spleen, intestines, and even sexual organs.

In another central section of a bantam chick, the peculiar lung structure of the bird is displayed, and the singularly beautiful insertion of rudimentary feathers. Those of the rat and dog (which are made longitudinally through the centre of the entire body) display the brain and whole length of spinal cord.

In another section of a human foetus of between two and three months' growth, it was seen that the vascular system had progressed to such an extent as to receive a partial carmine injection.

In carefully examining and comparing (with different degrees of magnifying power) these and similar preparations made at a very early period of foetal

life, it will be seen that a distinct *general mapping out of organs* exists, before an equally corresponding change can be traced in the shape and character of those cells which are concerned in forming these organs. There is no doubt, however, that a *differentiation* of character takes place in many of these cells to a far greater extent than is revealed by mere microscopic inspection; for when the preparations are tinted with carmine, this reagent exhibits the fact that *chemical changes* have taken place in many cells which differ very little in *appearance* from others.

We may thus see that special *local chemical* changes take place before the *physical structure* of each particular organ is fully developed.

The following particulars were also referred to:—

1st. The *large* relative size of the *liver*, in nearly all the specimens, as compared with the same organ in the adult animal.

2nd. The *smallness* of the *cerebellum* in the mammal foetus, and its *largeness* in the bird.

3rd. The *large* size of the spinal cord and posterior ganglia, both in the bird and mammal foetus, when compared with that of the adult animal.

On certain Points in the Anatomy of Lumbricus terrestris.

By Dr. ROLLESTON, F.R.S., Professor of Physiology in the University of Oxford.

On certain Points in the Anatomy of two Animals from the Mammoth Cave, Kentucky. By Dr. ROLLESTON, F.R.S., Professor of Physiology in the University of Oxford.

On certain Physiological Experiments with Ozone.

By Dr. B. W. RICHARDSON, M.A., F.R.C.P.

The following are the reliable facts known up to this time respecting ozone:—

1. Ozone in a natural state of the air is always present in the air in minute proportions, viz., one part in ten thousand.

2. It is destroyed in large towns, and with special rapidity in crowded, close, and filthy localities.

3. Ozone gives to oxygen properties which enables it to support life. In this respect it acts like heat: its effects are destroyed by great heat.

4. Ozone diffused through air in excessive quantities produces, on inhalation, distinct symptoms of acute catarrh—common cold.

5. When animals are subjected to air richly charged with ozone, the symptoms produced, at a temperature of 75°, are those of inflammation of the throat and pulmonary mucous membrane, and at last of congestive bronchitis, which in carnivorous animals is often rapidly fatal.

6. When animals are subjected for a long period to ozone in small proportions, the agent acts differently, according to the animal. The carnivora die, after some hours, from disorganization of the blood and separation of fibrine; but the herbivora will live for weeks, and will suffer from no acute disease.

7. The question whether the presence of ozone in the air can produce actual disease must be answered cautiously. Science has yet no actual *demonstrative* evidence on the point. But the facts approach to demonstration that common cold (catarrh) is induced by this agent. All else is as yet speculative.

8. During periods of intense heat of weather, the ozone loses its active power.

9. On dead organic matter undergoing putrefaction ozone acts rapidly; it entirely deodorizes by breaking up the ammoniacal products of decomposition.

10. There is an opposite condition of air in which the oxygen is rendered negative in its action, as compared with the air when it is charged with ozone. Air can thus be rendered negative by merely subjecting it, over and over again, to animals for respiration. The purification of such air from carbonic acid and other tangible impurities does not render it capable of supporting healthy life; but ozone restores the power. In a negative condition of air, the purification of the organic matter is greatly modified, and the offensive products are increased. Wounds become unhealthy, and heal slowly in such negative air.

11. There is no demonstrative evidence, as yet, that any diseases are actually caused by this negative condition of air; but the inference is fair, that diseases which show a putrefactive tendency are influenced injuriously by a negative condition of the oxygen of the air. It is also probable that during this state decomposing organic poisonous matters become more injurious.

12. As ozone is used up in crowded localities, and as it is essential that ozone should be constantly supplied in order to sustain the removal of decomposing substances and their products, no mere attention to ventilation and other mechanical measures of a sanitary kind can be fully effective unless the air introduced be made active by ozone. Fever hospitals and other large buildings in towns should be artificially fed with ozonized air.

A few Remarks on the Causes of the Cattle Murrain. By Dr. SHETTLÉ.

On Variability as manifested in the Construction of the Human Body.

By WILLIAM TURNER, M.B., F.R.S.E.

After alluding to the diversities in the external form of the body, which impart characters generally recognized as diagnostic not only of the race but of the individual, the author proceeded to show that variations also occurred in the different organic systems; and though no outward evidence of the existence of many of these variations may be manifested, yet they furnish the individuals in whom they occur with characters as distinctive as any peculiarities of external configuration. Hence, in the development of each individual, a morphological specialization occurs both in internal structure and external form, by which distinctive characters are conferred, so that each man's structural individuality is an expression of the sum of the individual variations of all the constituent parts of his frame. The illustrations advanced in support of the author's opinions were taken from the flexor muscles of the fingers and toes, and from the modifications in the form and size of a foramen called supracondyloid, which is occasionally met with in man, and of the objects passing through it. Of the variations in the flexor muscles of the fingers, the author especially pointed out the different slips not unfrequently met with connecting together the muscles or subdivisions of muscles situated not only on the same plane but on the superficial and deep planes. Of the variations occurring in connexion with the flexor muscles of the toes, the different modes in which the connecting slip passes from the long flexor of the great toe to the common flexor of the toes were analyzed in fifty feet. In eleven it ended solely in the deep tendon for the second toe; in twenty in the deep tendons for the second and third toes; in eighteen in the deep tendons for the second, third, and fourth toes; in one in the deep tendon for the second, third, fourth, and fifth toes. Each of these specimens again possessed characters which distinguished it from any other. In nine cases a connecting band passed from the common flexor to the long flexor of the great toe. Variations in the mode of arrangement of the accessory flexor, the short flexor, and the lumbricales in the fifty feet examined were also described. The differences which the supracondyloid process of the humerus exhibited in specimens dissected by the author were also pointed out, and the variations in the objects passing through the foramen which it assists in forming were summarized as follows:—1st. Both brachial artery and median nerve may go through it. 2nd. With a high division of the brachial artery, the ulnar artery and median nerve may go through it. 3rd. With a high division of the brachial artery, the radial artery and median nerve may pass through it. 4th. The median nerve, with only a small branch of the brachial artery, may pass through it. 5th. The median nerve, unaccompanied by any vessel, may go through it. Variability in construction was not manifested merely in different individuals; but in the same person corresponding structures on opposite sides of the body were by no means symmetrically disposed. How far these variations were produced by the conditions of life of the individual, or how far they might be due to hereditary transmission, were questions which for the present must be left undetermined.

GEOGRAPHY AND ETHNOLOGY.

Victoria Falls of the River Zambesi. By T. BAINES.

The author visited the Victoria Falls of the Zambesi in 1862, during a journey which he undertook, in company of Mr. James Chapman, with the object of traversing the continent of Africa, from Walvisch Bay on the west coast to Quilimane on the east, by way of Lake N'gami and the Zambesi river. They spent three weeks surveying the Falls, Mr. Chapman photographing, and Mr. Baines sketching the scenery; the result being a more accurate delineation than had previously been given of this remarkable geographical feature of Central Africa, which was discovered, as is well known, by Dr. Livingstone in 1855. The cataract is formed by the river, at a point where it is nearly 2000 yards wide, plunging into a deep narrow chasm (lying across its bed), about 400 feet deep and from 70 to 130 yards wide; the waters escaping from this by a narrow gate near the eastern end and pursuing their course to the lower country along a narrow gorge, prolonged for a great distance in extremely abrupt windings, traces of which are to be seen 800 miles below the cataract. A cloud of spray, resembling smoke, issues from the depths of the chasm, and rises, as was ascertained by the author, to a height of 1200 feet; from this and the roar of the waters is derived the native Makalolo name of the Falls, "Mosi-oa-tunya"—"the smoke sounding." A luxuriant tropical forest, teeming with animal life, surrounds the cataract, and also the river above it; but the country further down, lacking the fertilizing influence of the river, sunk deep below the surface, is of the usual African aridity. The author described in some detail the various excursions he undertook through the difficult country round about the Falls, in search of good points for sketching them; but owing to their great extent, it was impossible to obtain a good general view from any point, though many partial ones of great beauty may be found. The whole Fall is broken into a number of minor cataracts, one of which, at the western end, is more sloping than the rest, on account of the rocky edge of the Fall being worn away. At this part there is a greater volume of falling water than elsewhere, and it rushes down the steep incline in a fleecy, seething torrent, scattering spray that flashes like myriads of diamonds in the sunlight, the rainbow formed by the unclouded tropic sun upon the rising vapour being one of the most brilliant and beautiful objects it is possible to conceive.

Letter from Mr. SAMUEL BAKER to Sir R. I. MURCHISON.

"Khartum, April 30.

"MY DEAR SIR,—I arrived here yesterday, and trust to be in England shortly after you receive this. I thank you for your very welcome letter, which reached me in Unyoro, delivered by an Arab trader on the 20th of September, 1864. Your appreciation of my researches among the various Nile tributaries in 1861 gave me great pleasure, and was a timely stimulus at a moment when I was ill and broken down with fever.

"I had the good fortune to meet Captains Speke and Grant at Gondokoro, in February 1863. The object of my expedition being attained by meeting them, and by their discovery of the Victoria Nyanza Nile-head, I should have returned with them had not Captain Speke reported that he had heard of a lake called by the natives Luta Nzigé. This, he imagined, might be a second source of the Nile, and I at once determined to attempt its exploration.

"My boats departed from Gondokoro for Khartum with Captains Speke and Grant, but when I was about to start the whole of my men mutinied and refused to proceed, retaining possession of my arms and ammunition. The ivory traders of the place combined to prevent any European from penetrating the interior, fearing travellers' reports upon the slave trade. The chance of being able to proceed appeared hopeless. Being resolved not to be driven back, and finding it impossible to lead my men south, I at length induced eighteen of my mutineers to accompany me to the camp of one of the traders, E.S.E. of Gondokoro about 80 miles, whence I hoped to be able to alter my course. Having loaded my camels and asses, I started at night, without either interpreter or guide, neither of whom were procurable, all the natives being under the influence of the traders. On passing the station of an Arab trader, six days from Gondokoro, my men, who had previously conspired to

desert me at that spot, again mutinied; several absconded with arms and ammunition, and joined the trader's party. They, however, with the entire party, were massacred by the Latooka tribe two days after their desertion.

"A day's journey in advance of that station I met an Arab trader, whose heart I gained by presents. I persuaded him to supply me with porters, and to accompany me to the Unyoro country, where he might commence a trade with King Kamrasi. Thence I intended to strike west in search of the lake.

"Owing to a succession of difficulties and delays I did not arrive at Kamrasi's capital, M'rooli, N. lat. $1^{\circ} 37'$, until the 10th of February, 1864. The trader's party returned to Gondokoro, leaving me with my escort of thirteen men to proceed. After eighteen days' march I reached the long wished for lake, about 100 miles west of M'rooli, at Vacovia, in N. lat. $1^{\circ} 14'$. In respect for the memory of our lamented Prince I named it (subject to Her Majesty's permission) the 'Albert Nyanza,' as the second great source of the Nile—second, not in importance, but only in order of discovery, to the Victoria Nile-head. The Victoria and the Albert lakes are the indubitable parents of the river.

"The capital of Unyoro (M'rooli) is situated at the junction of the Nile and Kafoor rivers, at an altitude of 3202 feet above the sea-level. I followed the Kafoor to lat. $1^{\circ} 12' N.$, to avoid an impassable morass that runs from north to south; upon rounding this I continued a direct westerly course to the lake. The route throughout is wooded, interspersed with glades, thinly populated, with no game. My route lay over high ground to the north of a swampy valley running west; the greatest elevation was 3686 feet. The rocks were all gneiss, granite, and masses of iron ore, apparently fused into a conglomerate with rounded quartz pebbles.

"The Albert Lake is a vast basin lying in an abrupt depression, the cliffs, which I descended by a difficult pass, being 1470 feet above its level. The lake level is 2720 feet, being 1341 feet lower than the Nile at M'rooli; accordingly the drainage of the country tends from east to west. From the high ground above the lake no land is visible to the south and south-west; but north-west and west is a large range of mountains, rising to about 7000 feet above the lake level, forming the western shore, and running south-west parallel to the course of the lake. Both King Kamrasi and the natives assured me that the lake is known to extend into Rumanika's country to the west of Karagwé, but from that point, in about $1^{\circ} 30' S.$ lat., it turns suddenly to the west, in which direction its extent is unknown. In N. lat. $1^{\circ} 14'$, where I reached the lake, it is about 60 miles wide, but the width increases southward. The water is deep, sweet, and transparent; the shores are generally clear and free from reeds, forming a sandy beach.

"I navigated the lake in a canoe formed of a hollow tree for thirteen days from Vacovia, arriving at Magungo, at the junction of the Nile with the lake, in N. lat. $2^{\circ} 16'$. The voyage was long, owing to the necessity of coasting, and to the heavy sea, which, with a westerly wind, generally rose at 1 P.M. daily.

"At the Nile junction the lake had contracted to a width of about 20 miles; the shores were no longer clean, but vast masses of reeds growing in deep water prevented the canoe from landing. Mountains had ceased on the eastern shore, giving place to hills about 500 feet high, which instead of rising abruptly from the lake, like the mountains further south, were five or six miles distant, the ground descending in undulations to the lake. The entrance of the Nile is a broad channel of deep but dead water, bounded on either side by vast banks of reeds. From this point the lake extends to the north-west for about 40 miles, and then turns to the west, contracting gradually; extent unknown.

"About 20 miles north of the Nile junction at Magungo the river issues from the great reservoir, and continues its course to Gondokoro.

"I went up the Nile in a canoe from the junction; the natives would proceed no further north, owing to the hostile tribes on the lake shores. About 10 miles from the junction the Nile channel contracted to about 250 yards in width, with little perceptible stream, very deep, and banked as usual with high reeds, the country on either side undulating and wooded. The course from the junction up the river being east, at about 20 miles from Magungo, my voyage suddenly terminated; a stupendous waterfall of about 120 feet perpendicular height stopped all further progress. Above the great fall the river is suddenly confined between rocky hills, and it races through

a gap, contracted from a grand stream of perhaps 200 yards width, to a channel not exceeding 50 yards. Through this gap it rushes with amazing rapidity, and plunges at one leap into a deep basin below. This magnificent cataract I have taken the liberty of naming the 'Murchison Falls.'

"From that point I proceeded overland, parallel with the river through Chopi, and at length I reached Karuma, having been for some months completely disabled by fever, my quinine long since exhausted.

"Lake Albert Nyanza forms an immense basin far below the level of the adjacent country, and receives the entire drainage of extensive mountain ranges on the west, and of the Utumbi, Uganda, and Unyoro countries on the east. Eventually receiving the Nile itself, it adds its accumulated waters and forms the second source of that mighty river. The voyage down the lake is extremely beautiful, the mountains frequently rising abruptly from the water, while numerous cataracts rush down their furrowed sides. The cliffs on the east shore are granite, frequently mixed with large masses of quartz.

"On the eastern borders of the lake much salt is obtained from the soil; this forms the trade of the miserable villages which at long intervals are situated on the Unyoro shore. The natives are extremely inhospitable, in many cases refusing to sell provisions. Mallegha, on the west coast of the lake, is a large and powerful country, governed by a king named Kajoro, who possesses boats sufficiently large to cross the lake. The Mallegha trade largely with Kamrasi, bringing ivory and beautifully-prepared skins and mantles in exchange for salt, brass-coil bracelets, cowries, and beads, all of which articles, excepting salt, come from Zanzibar *via* Karagwé, there being no communication with the west coast of Africa.

"The actual length of the Albert Nyanza from south to north is about 260 geographical miles, independent of its unknown course to the west, between 1° and 2° south latitude, and of its similar course in the north, in lat. about 3° .

"I rejoice at having been able to accomplish this exploration without the assistance which the Royal Geographical Society so kindly offered. I enclose map of my route, with a list of elevations above the sea-level (taken by one of Casella's thermometers, subject to correction in England). Success having rewarded me for all hardships, I look forward with impatience to the pleasure of giving you more detailed information in person.

"Very sincerely yours,

"SAMUEL W. BAKER."

"Sir Roderick I. Murchison, K.C.B."

On certain Simious Skulls, with especial reference to a Skull from Louth, in Ireland. By C. CARTER BLAKE, Ph.D., F.G.S., F.A.S.L.

The author said the skull exhibited was the property of the Anthropological Society of London. It was presented to their Museum by Captain Montgomery Moore, who obtained it from Louth Abbey, in Ireland. Nothing more is known of its history. The attention which has been drawn, during the last few years, to the celebrated skull from the Neanderthal, in Germany, renders any skull which at all resembles it in its most striking aspect of peculiar interest. M. Pruner-Bey was the first who pointed out the close resemblance between the skull from the Neanderthal and those of existing Irishmen. Professor Wm. King, of Galway, in his comparison of the Neanderthal skull with the more normal examples of human crania, refers frequently to a skull from Corcomroo Abbey, County Clare, Ireland, which, from his description, appears to present some points of affinity with the skull from Louth now exhibited. The Louth skull was ovately dolichocephalic. The brow-ridges are large, and the points of muscular attachment are well marked. The frontal suture has been early obliterated, and no trace whatever exists. The length of the sagittal suture is 11.4 centimetres. Throughout the whole of the posterior two-thirds of its length, obliteration has proceeded to such an extent as entirely to obscure the indications which would have shown its proportions, direction, or serration. The lambdoidal suture is present on each side, in an upward direction, for about two inches from its junction with the *additamentum mastoidalis*. The coronal suture offers some points of interest. Partial obliteration has extended throughout the whole of its course, excepting the deeply serrated portion above the post-

orbital and temporal ridges. The condition of the sutures around the alisphenoid bone demands our special attention. It is only necessary to say that on the left side the spheno-frontal and spheno-parietal sutures are entirely closed, whilst not the slightest trace exists of their direction. Turning, however, to the right side, the shape of the posterior edge of the alisphenoid becomes manifest. A long narrow tongue of bone extends in front of the squamosal, and is partially confluent with the parietal, especially at the extreme anterior corner of the latter. It has also become, to a less extent, though still definitely, coalescent with the frontal bone. This coalescence is especially interesting, as, although upon the right side of the skull, it has taken place upon a spot apparently free from the erosive action which has taken place on the posterior right portion of the skull. It is only necessary to say that, with respect to the squamous suture, no peculiarities meet the eye of the observer. The connexion between the mastoid and squamosal bones is obliterated to a great extent, but not more so than is usually observable in aged individuals. The brow-ridges are exceedingly peculiar. Enormous frontal sinuses have developed a bony ridge, which extends above the eyes throughout the whole length of the supraciliaries, and is thickest and most pronounced immediately below the glabella. The supraorbital canal on the right side is higher than on the left. Proportionately to the size of the ridge, the supranasal notch does not appear deep. The forehead is rather low and retrocedent, apparently rendered more so by the great size of the supraciliary ridges. The curve of the frontal bone, backwards and upwards, is equable and smooth. When a line from the glabella to the inion is made horizontal, the greatest height of the skull is situated about an inch behind the junction of the sagittal and coronal sutures. When the Abbé Frère's line from the *meatus auditorius* to the centre of the coronal suture is made vertical, the most posterior part of the skull is situated about an inch and a half lower than the apex of the lambdoid suture, and the same distance above the inion. The line of greatest breadth of the skull will be found in a line drawn from the spot of greatest height to the apex of the mastoid process. The parietal bones are very slightly flattened between the line of the sagittal and the line of attachment of the temporal muscle. The traces of the latter are not remarkably prominent. From the above description of the skull, the author considered that the following conclusions can safely be drawn.

The contracted forehead is due to the premature closing of the sutures surrounding the alisphenoid bone, and the lower medial part of the coronal suture. In early life, the frontal and alisphenoid bones being firmly united with the adjacent ones in such a way as to form a bony plate, the same conditions were observed as described by Dr. B. Davis, in his paper on the Neanderthal skull. "It will thus be seen that there is nothing either of a simious character, or that might not have been expected in the low forehead of the Neanderthal skull, in which the brain had to grow and expand under a plate of bone, which appears to have been in a great degree in one solid piece. It was impossible to raise this plate of bone upwards; and the result, as will be seen, was a development to another direction. In the middle region of the calvaria, the sagittal suture being closed, the contained cerebral substance could only expand at the sides, in the situation of the squamous sutures; and here the Neanderthal calvarium seems not to lack development. But in the posterior region its greatest expansion took place, precisely because in this part was the open lambdoid suture, which admitted of the growth of the brain. In the figures of this imperfect calvarium, the superior occipital scale is seen to be bulged out, and the whole of what remains of the occipital bone is full and large—the compensatory result for the contracted anterior regions." The above words, which Dr. B. Davis applies to the Neanderthal skull, can be applied, *mutatis mutandis*, to the skull from Louth. The peculiarities which were alleged to be due merely to the premature closing of certain sutures, the fact is not remarkable that such skulls as the specimen, "1029 of Davis," or as the skull before us, should be encountered not unfrequently. Attention having been drawn to the influence which premature closing of the sutures produces on the form of the skull, it is probable that we shall find many other instances. But the occasional occurrence of such cases leads an anthropologist deeply to regret that such an abnormality as the

Neanderthal skull should have ever been put forward as an important link in the series of early forms, connecting man with the lower animals, and to hope that a similar error of generalization will not occur again in our science. Although to allude to the Neanderthal skull, in the present state of the controversy, may appear to some a superfluous digression, the lesson cannot be too often insisted on, that in examining a skull purporting to be that of "the missing link," it should have been worth while to have inquired whether its peculiarities were not in some degree traceable to the premature ossification of the sutures of the skull.

Explorations in the Interior of Vancouver Island. By R. BROWN.

An expedition, equipped by the Vancouver Island Exploration Committee, and commanded by Mr. R. Brown, explored a large portion of the hitherto almost unknown interior of Vancouver Island, in the summer of 1864. The party, which comprised an astronomer, an artist, and a naturalist, besides a staff of assistants and native hunters, first traversed the island from Cowichan Harbour to the fortified Indian village of Whyack, near the "False Nittinaht" of the Admiralty charts. During this journey the great Cowichan Lake was well explored. It was found to be 22 miles in length, and from one-half to three-fourths of a mile in breadth, surrounded by two distinct ranges of mountains, from 2000 to 3000 feet in height. From the lake Mr. Brown struck across a well-timbered country to the south-west until he reached the Nittinaht River; on this stream the party embarked in rafts, and arrived, after a dangerous journey down the rapids, at a broad inlet of the sea, 18 miles in length, the shores of which are studded with Indian villages. The inlet opens to the Pacific by a very narrow passage between cliffs. The next journey was performed by Lieut. Leech, the second in command, when the island was crossed a second time, from Sooke Harbour to Cowichan Harbour. The expedition then proceeded by sea to Nanaimo, on the east coast, and after exploring the various branches of the Courtenay River, and discovering extensive beds of coal, again crossed the island in the direction of the Central Lake, discovering, on the way, five new lakes and several rivers. The Central Lake they found to be a dreary expanse of water, 18 miles long. Leaving its shores they proceeded by land to Klee-coot Lake, another large sheet of water, and thence to the Alberni settlement; finally recrossing to Nanaimo. Mr. Brown and Lieut. Leech report the whole of the interior as rugged and mountainous, but well wooded; gold and other minerals were found in various places, but very little pastoral land. Between Nanaimo and Alberni there are four distinct ranges of mountains, the culminating peaks of which range from 3700 to 5500 feet in height.

Ascent of the River Purus. By W. CHANDLESS.

The Purus is one of the least known of the great tributaries of the Amazons, and has been a subject of great interest, not only to geographers but to the people of Peru and Brazil, from the fact that a few native traders sailing up it in canoes have reported it free from impediments to navigation, and from the supposition that the fine stream, the Madre de Dios, flowing from the southern provinces of Peru, formed its head-water. The Brazilians were further interested in it on account of the report that there was water communication between it and the great river Madeira above the cataracts, which might serve as an outlet for the productions of the interior province of Matto Grosso. In modern times, the Brazilian Government had despatched four expeditions from the Amazons up the river; but none of them had solved the problems connected with it, or made accurate geographical observations during the voyage. Mr. Chandless, therefore, undertook to explore it in detail by his own unaided resources. He obtained, by a fortunate circumstance, a crew of Bolivian Indians to navigate his canoe, and taking with him a complete outfit of instruments for observation, entered its mouth on the 12th of June, 1864. He continued his voyage until, on the 23rd of December, the river was so narrow and impeded with rocks that he could go no further. He was then 1866 miles from its mouth, and at an altitude of only 1088 feet above the sea-level. He penetrated as far as he could up both of the terminal forks of the river; but neither proved to be the Madre de Dios, being about 2° of latitude to the N.N.W. of that river, and

lying in a position in which one of the eastern tributaries of the Ucayali is marked on the maps. The forest was everywhere so dense and lofty that from no point could a view be obtained of the Andes, although Mr. Chandless supposed they would be visible. Near these upper waters a primitive tribe of Indians was met with, who had never had intercourse with white men or with the trading Indians lower down; they were ignorant of the use of iron, and possessed hatchets of stone.

On the Origin of the Gipsies. By Dr. CHARNOCK.

On Cannibalism in Europe. By Dr. R. S. CHARNOCK, F.S.A.

The author commenced by avowing that he was aware that the subject of his paper was an unpalatable one, but asked his hearers to take into account the fact that the inhabitants of Europe were at one time quite as savage as many existing cannibal races. He quoted the testimony of many ancient authors in favour of the existence of cannibalism among the Læstrygones, the Lamiæ, and the Cyclopes. Many ancient writers had advocated the theory that it was more reasonable to eat human flesh than to leave it a prey to worms and to putrefaction. A French author had stated that human flesh did not differ appreciably in taste from that of domestic animals, and that the moral crime of cannibalism consisted in the murder and not in the use of the body as food. St. Jerome's well-known testimony in favour of the existence of cannibalism amongst the Attacoli or Attacoti of Scotland was cited, as well as that of Diodorus Siculus respecting the *Galatæ*, and that of Herodotus respecting the Issedones. In the middle ages cannibalism was usually attributed to all nations which had not embraced Christianity; it was fashionable to bring the accusation against enemies, and the Saracens and Christians during the Crusades charged each other with devouring the flesh of slain prisoners. According to Reinard, Tarik the Moor served up the flesh of his prisoners to his troops. In Milan, in 1519, a woman was condemned to death for enticing into her house children, whom she killed and salted. In 1782 a French bandit was broken on the wheel for the murder of young women and children whom he devoured. In the reign of Elizabeth a Scotch bandit, Sawney Bean, was executed for cannibalism, and other instances were cited from Germany and Spain. In the latter country a law existed by which a father besieged in his lord's castle and pressed by hunger might eat his own son rather than surrender the castle. During the siege of Calahorra, this law was acted on.

The Oriental Negro. By J. CRAWFURD, F.R.S., F.G.S.

Under the designation of "Oriental Negroes," this paper describes no fewer than seven different races, all differing not only from the African Negro, but widely differing among themselves in physical form and in language. The Negroes of the Andaman Islands, of the Malay Peninsula, are pignies of some 4 feet 9 inches high; the Papuan Negroes of New Guinea rise to the average of 5 feet 4 inches; while those of the Fiji group reach 5 feet 7 inches, or are of the ordinary stature of Europeans. In view of all the Negro races of man, whether Occidental or Oriental, the conclusion to which the writer comes is, that they are inferior to all the other races in juxtaposition to them. In Africa the Negro is inferior to the Mauritanian, the Egyptian, the Nubian, and the settlers from Arabia and India. In the Malay Peninsula, in the Philippines, and New Guinea, he is inferior to the Malay, and in the isles of the Pacific he is immeasurably below the brown straight-haired Polynesian. It is especially his mental inferiority that makes the Negro everywhere liable to be domineered over or enslaved by the more highly gifted races.

On the Physical and Mental Characteristics of the African or Occidental Negro.

By J. CRAWFURD, F.R.S., F.G.S.

The Negro was defined by the author as a human being with the hair of the head and other parts of the body always black and more or less woolly; with a black

skin of various shades; dark eyes, a flat face, depressed nose, jutting jaws, thick lips and large mouth; with oblique incisor teeth. To this was to be added a peculiar odour of the skin, offensive to and unknown in the other races of man. He did not think that the form of the skull, in so far as it is the brain-case, could be insisted on as a criterion of the African Negro, for he did not believe it had any characters by which it could certainly be distinguished from the skulls of nearly-allied races, such as those of the Abyssinians and of the Oriental Negroes. The word Negro was obviously a corruption of the Latin adjective for "black." The intellectual character of Negroes might be judged of by the low grade of civilization which they had attained, notwithstanding that their country has furnished them with nearly all the appliances that contribute to social progress—fertile soil, cultivable cereals, domesticable animals, useful metals, and so forth—in a far higher degree than the most advanced nations of native America and the fairer race of the Pacific isles. One remarkable example of the obtuseness of the African Negro was his never having tamed the elephant, which is far more abundant in his country than in any other part of the world. The African elephant is, indeed, a distinct species from the Indian, but it is equally amenable to domestication, as sufficiently attested by the well-ascertained fact of the African being the elephant domesticated by the Carthaginians, a people of Asiatic origin, whose example the African Negroes have not had the capacity even to imitate. The Negro also had never shown ingenuity enough to invent letters, symbolic or phonetic.

On Cannibalism in Relation to Ethnology. By J. CRAWFURD, F.R.S., F.G.S.

The argument of this paper was to the effect that the early races of men, originally eaters of the raw flesh of animals, were driven at a subsequent stage of progress, when wild animals had become scarce, to eat the bodies of their slain enemies. This was the stage of cannibalism, and it ceased when, pressed by a diminishing supply of food, human ingenuity was stimulated to invent means for augmenting it by cultivating vegetable food and domesticating animals. In classic times the Greeks and Romans, and all the tribes and nations with which they held intercourse, had reached this stage, and Herodotus is the only classic writer who charges two Asiatic nations with cannibalism. We have other evidence, however, of the ancestors of the most civilized nations of Europe and Asia eating human flesh, in the disinterment from grottos of human bones artificially split for the extraction of marrow, and so forth. Cannibalism was formerly, and is still practised by South American Indians, as well as by the New Zealanders and the inhabitants of many islands in the Pacific and in the Malay Archipelago. The author particularly cited the cannibalism of the New Zealanders as a case in support of his view that savages are prompted to cannibalism by the deficiency of other animal food.

On the Isthmus of Panamá and Inter-Oceanic Ship Canal Routes.

By Dr. CULLEN.

This was a review of the various routes which have been hitherto proposed for a ship canal across the narrower parts of America, namely, those of Tehuantepec, Honduras (from Puerto Caballos to Fonseca Bay), Nicaragua, Chiriqui, Panamá, Chepo, Atrato and San Juan, Atrato, Napipi and Cupica, Atrato and Truando, and lastly, that of Darien, from Caledonian Harbour to the Gulf of San Miguel. The author gave the preference to the last-mentioned line, which he had himself explored some years ago. It is the only one, except that of Chiriqui, which supplies the indispensable conditions of a good harbour at each end. The failure of the various expeditions sent out in 1853 to discover a practicable line for a canal, was attributed by the author to the refusal or inability of the surveyors, Mr. L. Gisborne and others, to examine the only point where a passage of the mountains was practicable—a break in the chain inland of Caledonia Harbour. The Cordillera is stated to consist here of two separate chains, the extremities of which overlap each other, leaving between them a valley, running at an angle of about 20° with the coast. In 1860 a partial exploration of this line was made by MM. Bourdiol, De Puydt and Bourcier, and again, in 1861, by the same gentlemen and M. de Champville. In 1864 a further examination was made by MM. de Puydt and Tronchon; and

in the spring of the present year applications were presented to the Congress at Bogotá, by two companies and three firms, for a privilege to cut a canal by this line. The length of a canal in this part would be thirty-five geographical miles. A careful survey is still required of the oblique valley in the Cordillera, the highest point of which probably does not exceed 250 feet.

On the Darien Indians. By Dr. CULLEN.

On the Influence of Civilization upon the development of the Brain in the different Races of Man. By ROBERT DUNN, F.R.C.S.

The author began by premising, as a basis for his observations, the following postulates:—

1. That the brain or encephalon is the material organ of the mind.
2. That there exists a close correspondence in form and size between the cerebrum and its outward bony covering—the skull; so that the varying forms of the human cranium indicate, as outward and visible signs, with certain well understood qualifications, corresponding differences or changes in the shape and size of the cerebral substance within.
3. That the genus *Homo* is one; and that all the races of the great family of man are endowed with the same intuitions, sensational, perceptive, and intellectual—the same mental activities, however they may differ in degree; and that they all have the essential constituent elements *in common* of a moral, religious, and intellectual nature.

He waived the question as to the monogenesis or polygenesis of man; but asserted that from all historic times there have existed, and do still exist, aboriginal and typical races of men, widely differing from each other, and easily distinguishable by well-marked physical and psychical characters: such, for instance, are the Negroes of Africa, the Mongols of Asia, the red men of America, and the white men of Europe. From time immemorial, he said, there have always existed, besides the rude and savage hordes of hunters and fishers, two forms or phases of civilization—the *nomadic* or the *pastoral*, and the *agricultural*; the former essentially *stationary* in its character, but the latter eminently and strikingly *progressive*.

Now, among the purely nomadic races, Mr. Dunn observed, where civilization is stationary, there exists, as might be expected, a *uniform sameness* and *characteristic fixity* in the shape of the head, strikingly in contrast with what is seen to prevail among the agricultural races and cultivated Europeans. He dwelt on the importance of viewing in contrast, the typical crania of the Negroes or Australian savages, the Mongolian nomades, and the cultivated Europeans; maintaining that, as the skull is the outward measure and index of the brain's development within, we are able fairly to estimate the relative size and comparative development of its three great divisions, the anterior, middle, and posterior lobes; nay, among the typical races, to recognize *distinctive characters* impressed and stamped upon their varying crania, as indisputable evidence of *degradation* and *elevation* of type. In proof of this, he adverted to the *prognathous* type as one of *degradation*. In striking contrast to this, he adduced as a type of *elevation*, that of the *orthognathic*, seen among the European nations, the Saxons, Celts, and Scandinavians, where the jaws are upright and not projecting, the face scarcely, if at all protruding beyond the forehead; and where, in place of the narrow, low and retreating forehead, associated with largely developed, massive, and projecting bones of the face and jaws, we are struck with the symmetrical contour of the head, its size, and lateral fulness; but above all, with the elevation of the forehead in proportion to the size of the face, and with its broad, expansive, and towering height, clearly indicating a harmonious development of the whole brain, and a special fulness in the intellectual and moral regions.

From the skulls he proceeded to the comparison of the brains themselves, and stated what were the views and convictions of his own mind, viz., that the anterior lobes are the seat of the intellectual, the middle of the personal or individual, and the posterior of the social and affectional activities or attributes of the human mind.

He remarked, that as the anterior lobes of the brain are the seat of the intellectual

activities of the mind, fulness of development and complexity of structure are sure indications of elevation of type; and that the converse, as Gratiolet, from extended observations has amply shown, is equally true, viz., that simplicity of structure and perfect symmetry of shape and arrangement in the convolutions on both sides of the hemispheres, are indisputable marks of degradation of function.

He looked forward to the microscopical examination of the ultimate structure of the grey matter of the brain in the typical races of man, as pregnant with the most interesting and instructive results. Already Dr. Beale and Mr. Lockhart Clarke had proved to demonstration that *perceptible differences* exist in the minute anatomy of the grey matter of the convolutions in the brain of man and that of the monkey and the highest anthropoid apes. Dr. Beale had succeeded in demonstrating the connexion between the nerve-cells and the very finest fibres in the grey matter of the convolutions; and he maintains that the central cells of every nervous instrument form, with the peripheral nerve-cells and connecting nerve-fibres, *uninterrupted circuits*; and that all nerve-cells are connected with, or give origin to, at least two fibres. Mr. Lockhart Clarke had shown that certain *structural differences* are seen in the grey matter of the convolutions of the anterior, middle, and posterior lobes.

He concluded by adverting to the historical bearings of his subject—to the evidence which is presented by history of the conversion, in *time*, of one type of humanity into that of another, under the influence of outward circumstances, social states, and intellectual culture. As illustrative instances, he adduced the case of the transplanted Negroes in America and the West Indies; amongst the Asiatic or Mongolian races, the Turks of Europe and the Magyars of Hungary, and amongst ourselves, as instances of degradation, the Irish of Leitrim and Sligo, and the vagabond nomades who infest our large cities and towns.

In proof of cranial alterations for the better, from the influence of improved social conditions and higher intellectual activities, he directed attention to some casts exhibited, taken at different periods from the same individuals. In each case the interval was not a period of leisure, but of great mental activity; and the result in each was seen in the decided enlargement and development of the anterior part of the forehead.

On the Worked Flints of Pressigny le Grand. By J. EVANS, F.R.S.

Pressigny le Grand is a small town situated on the river Claise, about thirty miles to the south of Tours. The peculiar worked flints which the author had found there in January last, in company with the late Mr. Christy and Messrs. Brouillet and Lartet, were discovered in a soil of red loam overlying bryozoic chalk, and from their resemblance to pounds of butter, have received from the peasants the name of *livres-de-beurre*. Their form has been given by striking a succession of flakes from the sides of a mass of flint until a boat-like contour has been obtained. Looking at a number of them arranged together, the eye is struck by their great similarity of form; and the regular and neat manner in which their edges are chipped would at first sight lead to a presumption that they were intended for implements, such as ploughshares, or some kind of large and heavy axes. Those persons, however, who have paid most attention to the subject have come to the conclusion that they are not implements at all, but rather the *nuclei* or cores from which long flakes or knives have been removed, and which have then been thrown away as having served their purpose. The supposition of Messrs. Robert and Élie de Beaumont, that they are the refuse arising from the manufacture upon the spot of flints for fire-arms, was believed to be untenable, on account of their utter dissimilarity to the cores known to be the result of gun-flint manufactories. It seems more probable that there must have been in prehistoric times a settlement on the spot, of men who manufactured long knives from these flints, and afterwards bartered them away, than that they were worked by various tribes who visited the spot as one abounding in the raw material for their cutlery.

Language and Ethnology.

By the Rev. FREDERIC W. FARRAR, M.A., F.E.S., &c.

It was the object of this paper to establish the conclusion that all inferences

which could at present be drawn with safety from the admitted facts of philology, tend strongly to favour a belief in the primitive diversity of languages, and therefore of human races. After noting the utter failure of all attempts to discover a primeval language from which others had been derived, the author argued that all on which we could at present insist, was the unity of the Semitic and Aryan families of language, and of one or two comparatively small sporadic groups. He denied that the unity of the so-called *Turanian* family was in any way established, and endeavoured to show that the name itself was misleading and chimerical, and that the arguments in favour of the original unity of these languages were shadowy and inconclusive. But even if the existence of a genetic connexion between the members of this wide group were admitted, the author urged that there was no possibility of deriving the number of these different families of language, either from one another or from any one common source. The radical and fundamental differences of conception which mark the Aryan and Semitic grammatical systems, were such as marked them as the intellectual product of two wholly distinct races, and there was no conceivable theory, even if a vast series of years were postulated, which would account for the derivation of the one from the other; and each of these systems was separated from Chinese by a still broader and deeper chasm, a chasm which could not be bridged over by any legitimate deduction from the known history and indisputable facts of the growth and decay of languages throughout the world. Hence it was concluded that the languages, no less than the flora and fauna of various nations, originated in different geographical centres.

On the Exploration of the Holy Land, as proposed by the Palestine Exploration Fund. By GEORGE GROVE, Hon. Sec.

The author said, notwithstanding the numerous books of travel that had been published respecting Palestine, we were still in great ignorance with regard to much that concerned the life of the existing people. No work on that country had been written similar to that of Mr. Lane on the Modern Egyptians. It had been said with truth that if the Lower Nile valley and its inhabitants were swept away, we should still have preserved to us a complete picture of the nations which have peopled it, in this exhaustive work. Now, what had been done for Egypt it behoved us to endeavour to do for the Holy Land. We knew nothing of the treasures of ancient Egypt until they were commenced to be dug up by Belzoni. The explorations of Sir Henry Rawlinson and Mr. Layard had, in the same manner, disclosed the remains and led to much of our knowledge respecting the great nations which peopled the plains of the Euphrates and Tigris. The same still remained to be done in Palestine. There must be a vast amount of treasures in arms, coins, weapons, and utensils, still buried in the soil, which would throw great light on the domestic life of the Jews. The soil of Palestine was virgin; not a spade had yet been put into the mounds of ruins which existed in that country. There were great difficulties to be surmounted in the way of carrying out these explorations, the chief one being the difficulty which had hitherto existed of travellers being able to remain long enough in the country. Besides, it was in the unfrequented districts that the Exploration Society was most desirous of penetrating, and in these places travellers especially qualified, and having the means of remaining long, are required to pursue continued investigations. One most cogent reason for undertaking the exploration was furnished by the fact, that the ancient traces were fast passing away, and the native customs of the people disappearing before the advance of Western civilization. There was a curious orgy, probably very similar to those formerly practised by the priests of Baal, which had almost fallen into disuse, and such customs as this, if now investigated, would tend to throw great light on the customs of the people. Much also still remained to be done in the geography of the land. As an instance of the confusion which still exists in the orthography of places, he would mention the fact of a place being named in one map *Embarreg*, and in another *Mubughghik*. The sites of many of the most celebrated places in Holy Writ were yet matters of uncertainty. In short, it was a systematic, leisurely, and thorough investigation of the Holy Land which the Society proposed to themselves to undertake.

*On the Comparative Anthropology of England and Wales.**By D. MACKINTOSH, F.G.S.*

The author begins by referring to a paper read by him before the Ethnological Society of London in 1861, and published in their 'Transactions.' Since then he has had many opportunities of confirming and adding to the theories and facts contained in that paper. He believes that in most parts of England the masses of the population seldom shift their localities, and that internal migrations are generally limited to the middle and more affluent classes. The fact that different dialects still linger in different parts of England is a proof that the inhabitants have not become so interblended as to destroy typical distinctions, or render classification impossible. During many years the author has succeeded in tracing a difference in type or race in various parts of England and Wales; and he believes that this difference is not the result of accident, but exists through hereditary descent. It may have originated in ancient "family variations" in certain districts of Europe which have acquired a persistent character, and which in some cases have become so hardened as to resist amalgamation. In North Wales the author has been able to reduce the principal differences observable in the physical characteristics of the inhabitants to two types, one of which, for historical reasons, he provisionally calls Cymrian:—skull rather narrow and elongated; hair brown, frequently very dark; eyes sunk and ill defined; sudden sinking in under the cheek-bones; face long, and nose more or less prominent. The other he calls British:—skull approximately square; face rather flat, the upper part broad, and the lower angular; eyes sunk, and generally half-closed; chest and shoulders very broad. The first type predominates in North Wales; and there the second is common, though much more prevalent in South Wales, where it coexists with a very well-marked type, to which the author gives the name Gaelic, as it is to be found not only in Wales, but among the lower classes in France, the south-west of England, the Highlands of Scotland, and the west of Ireland:—skull elongated backwards; forehead retreating, with the lower part of the face projecting; nose more or less concave, with a great distance from the nose to the mouth. The British and Gaelic types coexist with the Saxon in the south-west of England, but the latter is most prevalent in Sussex, some parts of Hampshire and Berkshire:—skull intermediate between square and round, slightly elongated, and small in the occipital region; light brown hair and prominent blue eyes; low cheek-bones, broad, smooth, and round face; features excessively regular. The author believes there is a tall and convex-profiled type in the eastern part of the Isle of Wight and in central Kent, to which he applies the term Jutian. He describes a type intermediate between Jutian and Saxon, and thinks it may possibly be Frisian. In the Midland Counties, and throughout a zone running northwards through the West Riding of Yorkshire into Durham, there is an extensively-prevailing type, with lateral variations, which he supposes must have settled in England under the name of Angles. The complexion is very fair, and in many respects this type resembles the Saxon, though the features are rather sharper, and the figure not nearly so rotundiform. In Cumberland, and other districts shown by Worsaae to be inhabited by descendants of Norsemen, the author has not been able to make out a very distinct predominating type. He has no hesitation in asserting the existence of a strikingly marked and strongly persistent Danish type in districts where Danes must have settled according to history, especially Lincolnshire:—skull rather narrow, elongated, and elevated backwards, with projecting occipital region; hair and complexion more or less ruddy; high nose and prominent cheek-bones; long or rather long face, tall frame, and swinging gait. The author describes the mental peculiarities of the different types; speaks more favourably of the North Welsh than most writers, especially as regards their frugality, industry, temperance, social order, &c. The Danes are sanguine, ambitious, and energetic, with great aptitude for progression in the active affairs of life, but deficient in cogitation. Saxons are characterized by extreme moderation accompanying individuality, and an equal absence of great defects and extraordinary talents. Gaels are quick in perception, deficient in foresight, excitable, and strong in attachment. The author concludes by stating that he has intentionally left details relating to anatomical structure and complexion out of consideration, as Dr. Barnard Davis and Dr. Beddoe have taken up these departments, and will soon be

able to connect them with the evidence of distinct types furnished by physiognomy and mental characteristics. As we may learn from the history of geology, it will be only after the results of distinct lines of investigation have been grouped and generalized, that we can succeed in establishing fundamental principles on which the superstructure of comparative anthropology can be safely erected.

On North Polar Exploration. By C. R. MARKHAM, F.R.G.S.

The paper was a recapitulation of the arguments which the author and Captain Sherard Osborn had urged before the Royal Geographical Society, during the last Session, in favour of an expedition to investigate the unknown region around the North Pole. The introduction of the subject to the Section was about thought appropriate, as the governing body of the British Association was about to nominate a Special Committee for the purpose of representing to Her Majesty's Government the advantages to various branches of science which would accrue from such an expedition. Of the two routes towards the Pole which had been proposed, namely, those of Smith Sound and Spitzbergen, the author gave a decided preference to the former. He contended that it was impossible to reach the Pole or perform much scientific work by a sea voyage like that proposed *via* Spitzbergen, and Sir L. McClintock agreed with him in the opinion that the only way of accomplishing these objects was by sledging parties from Smith Sound. An additional reason for the preference of Smith Sound by an English expedition is now supplied by the circumstance of the Germans having recently commenced, at the invitation of Dr. Petermann, the organization of a North Polar expedition to go by the Spitzbergen route. A pioneer vessel started a few days ago, and although it had broken down shortly after leaving Hamburg, there was little doubt that the attempt would be renewed next year. The route *via* Spitzbergen was therefore preoccupied; and we ought to concentrate our energies on the only alternative route, namely, that of Smith Sound.

Results of Surveys relating to the Water Supply of Jerusalem.

By Capt. T. McNEILL and Capt. WILSON, R.E.

This was an elaborate Report to the Syrian Improvement Committee, by the engineers employed, of their surveys in the neighbourhood of Jerusalem, with a view to improve the water supply of the city, and was introduced, with additional remarks, by Dr. T. Hodgkin. The survey was undertaken in the autumn of 1864. The question of the water supply of Jerusalem had been, from an early period, of much interest, the more so on account of the natural difficulties which attended the subject. Looking at the remains of ancient works, there is nothing to indicate that Jerusalem ever had a large supply of water brought from a distance. The fact of the skill shown in procuring and conveying the small quantity of water by the conduits to the town, and in the construction of reservoirs for catching the surface water, shows that this necessary element must always have been scarce. The chief supply must have consisted of rain-water collected within the town and stored in tanks, as in the present day. Jerusalem is about 2700 feet above the Mediterranean, and 4000 above the Dead Sea, and is placed pretty nearly on the crest of the hills which define the watershed of the country. The road from Jerusalem to Bethlehem on the south, and to Bireh on the north, roughly marks this line. The road to Bireh rises from Jerusalem, Bireh being about 300 feet above the city. The country north of Bireh maintains its elevation for some distance; but here, as in nearly all cases, the country is cut up by valleys, which form a very peculiar feature, influencing not only the landscape but the water question. The district around Jerusalem consists principally of the steep sides of valleys which twist and encircle each other, their general direction being towards the Mediterranean on the west, and the Dead Sea on the east. The valleys are deep, the sides rocky and bare of soil, which appears to have been carried to the valley-bottoms by the winter rains, and the soil absorbs the rain, instead of allowing it to run over the surface. The cause of the present sterility of the district is the destruction, by neglect, of the artificial terraces which probably existed formerly, and which, by retaining the soil on the steep slopes, led to the ancient fertility of the country. The entire absence

of streams of water in the valleys leads to the belief that there exist subterranean water-courses. The Brook Kedron is crossed by an arch 9 feet wide. In some years no water at all flows under the arch. After three or four days' rain it will run on the surface for a few hours $2\frac{1}{2}$ or 3 feet deep, but ceases to flow in one or two hours after the rain abates; if, however, heavy rain continues with little interruption for ten days, the stream will flow on for two or three days after the rain has stopped. The depth of the soil in the valley-bottoms is probably very great; in the valley of Urtas it was found to be more than 20 feet. The valleys are consequently very ill adapted for reservoirs of water, although the rain-fall is amply sufficient. The nearest approach to a good site is the Wady-el-Byar, on the road between Jerusalem and Hebron. The authors found no trace of ancient irrigation works; the Pools of Solomon would only water 65 acres for six months in the year at the moderate depth of 2 feet, spread over the area watered. Near Nablus, and at other distant places, there are large streams of perennial water flowing out of the rock; these might (at a very considerable cost) be carried round the slopes of the hills and conveyed from valley to valley for irrigation purposes. The ancient reservoirs for rain-water, of which there are many, are in a ruinous state, except the upper Pool of Gihon and Hezekiah's Pool. The former is 315 feet long, 208 feet wide, and 20 feet deep, and holds about 8,000,000 gallons, which, allowing 2,000,000 for evaporation, gives 6,000,000 as the annual available supply of the pool. Hezekiah's Pool holds about 4,000,000 gallons. Careful measurements and details of construction of the various reservoirs are given by the authors, with suggestions for their repair; their total capacity would then be 44,147,000 gallons. Deduction would, however, have to be made for evaporation, which, calculating the probable amount of annual evaporation in this dry climate, with its mean temperature of $62^{\circ}6$ at 60 inches, would be 8,881,562 gallons. In the temperate zone, with a mean temperature of $52\frac{1}{4}^{\circ}$, the annual evaporation has been found to be between 36 and 37 inches. On the coast of South America (north latitude $10^{\circ}30'$), with a mean temperature of $81^{\circ}86$, it was ascertained to be more than 100 inches annually.

McIntyre's Journey across Australia, and Discovery of Traces of Leichhardt.
By Dr. F. MUELLER (Melbourne).

Mr. Duncan McIntyre and Mr. Barnett, with a party of three natives and twenty-five horses, started on the 21st of June, 1864, from the cattle stations on the River Paroo, to explore the country for cattle-runs and dray-routes, shaping their course towards the new settlement in Northern Australia. They reached Cooper's Creek after a march of twenty-two days, crossing the creek about 50 miles below the junction of the Thompson. Excellent country was found to the westward of the Paroo, but no permanent water. From Cooper's Creek they continued until Burk's track was crossed, and so far no difficulty in conveying stock was met with. The course was then changed for the head waters of the Albert River. The Flinders was struck on the 18th of August, a little south of Donor's Hills, and the river followed from that point to the sea; the journey from Cooper's Creek to the sea having occupied thirty-four days, being a little more than half the time taken by either Burke or McKinlay. The country to the north-west of the point where Cooper's Creek was crossed was very indifferent for a day or two, and waterless. It gradually got better on reaching a water-system in which four new rivers were found, the first of which was named by Mr. McIntyre the *Docker*. It then improved daily, and splendid sheep country was crossed in that part where the Stony Desert of Sturt is laid down. The ground in places was, however, covered with fragments of stones, and in some places "paved," as described by Sturt, for a few miles. On the whole, it was found to be a good grazing country, and particularly well adapted for sheep. A hundred miles or so to the south of the tropic, the country assumes a high, undulating character, with beautiful smooth downs; and it continued magnificent the whole way from this to the coast range. From the Gulf of Carpentaria to the banks of the Darling an excellent road might easily be made, along which a buggy could be driven without meeting with a single impediment. The Flinders River district is now peopled by squatters down to within about 280 miles of the Gulf. The party did not take with them an ounce of meat, but carried

plenty of ammunition, relying on game for food. Bush turkeys were seen everywhere, but were especially numerous in the neighbourhood of the Gulf. Pigeons, too, were found in thousands; altogether they fared well on the game shot by them, and had no reason to regret not having brought a supply of meat. Fish also were caught in large numbers in all the creeks, the party frequently taking more than could be eaten. The supposed traces of Leichhardt, discovered by Mr. McIntyre, consist of two trees, near the bank of the Flinders, marked each with a single L cut evidently by a skilled hand, and two old strayed horses with illegible brands on both of them. It is contended by Dr. Mueller (one of the former companions of Leichhardt) and others in Melbourne, who are now taking an active part in organizing a new expedition to search for further traces of Leichhardt, that the marked trees denote undoubtedly a Leichhardtian camp. They are situated on the western side of the main east branch of Flinders River, in latitude 20° S. The bark has encroached to the extent of four or five inches on the incision of the letters, showing a much greater age than that of Landsborough's camps, who also travelled in this direction. The last communication from Dr. Mueller announces the successful progress of his scheme for a new expedition. A "Ladies' Committee" has been organized and a vigorous attempt made to raise £3000 by subscription. It is hoped that some member of Leichhardt's lost expedition may be found still living in the far interior, notwithstanding that seventeen years have elapsed. Under any circumstances it is contended that the "Ladies' Expedition" will be likely to accomplish what Leichhardt intended, namely, to open up the unknown great western half of the continent.

Arctic Exploration. By Rear-Admiral E. OMMANNEY, F.R.A.S.

There are before the public two propositions for proceeding to the North Pole; the one making Smith's Sound the base of operations, the intention being to leave the ships in a secure position, from whence it is proposed to reach the Pole by travelling over the ice with sledges, making a sledge journey of it, on the supposition that land will be found extending itself towards the Pole from Smith's Sound. The other is from Dr. Petermann, who advocates in two very able and well-digested papers, the course of penetrating into the icy seas between Spitzbergen and Nova Zembla, on the theory that a warm current flows from the coast of Norway in that direction into the Polar Sea, extending itself to the vicinity of the Pole, and that the influence of this warm current of water is operative in raising the temperature of the sea, thus rendered free from ice obstructions, and available for navigation contiguous to the Pole. The chief obstacle to surmount, he considers to lie in the outer barrier of floes and packed ice, forming a moveable band of about five degrees of latitude in extent; so that after pushing the ships through this barrier, they would enter a sea easy of navigation, extending to the highest latitude, no doubt to the Pole itself. Certainly, on looking at the globe, where can we find a more favourable point to enter the Polar Sea? We have in the Spitzbergen seas the largest and widest openings from the North Atlantic Oceans; the Spitzbergen Islands have been circumnavigated, and their western shores are stated to be clear of ice in the summer. On glancing at the chart, it will be observed that the Polar region to be explored is that vacancy contained within the circle of the 80° parallel; but it is necessary to state that up to the present time no attempt has been made to reach the Pole with suitable vessels armed with proper instructions; for hitherto in all the voyages to these regions the seas were abandoned by order at the very best season for making an advance to the Pole.

The author also called to notice the fact that we have made but one attempt in this country to reach the North Pole, viz., that of Parry, in 1827; all the other expeditions have been undertaken with a view to make N.W. and N.E. passages to India and China.

Of the two routes now under discussion the majority of Arctic officers are in favour of making the attempt by the Spitzbergen seas. Certainly these seas offer the shortest route from Great Britain to the Pole. There are so many advantages to be advanced in behalf of making Spitzbergen the base of operations, that the author is induced to give that route his strongest recommendation in preference to proceeding *viâ* Baffin's Bay, and for the following reasons:—

1st. The Spitzbergen seas are more free from ice than any other part of the Arctic seas.

2ndly. The Western shores are clear of ice in summer, affording an open navigation between a dépôt fixed at Spitzbergen and England.

3rdly. It affords reasonable hopes for effecting the search of the Polar region in one season.

4thly. There are good harbours in Spitzbergen; the climate is more temperate than that of Smith's Sound; animal life is more abundant; driftwood for fuel is found on its shores.

Hitherto no proper effort by a suitable vessel has been made to reach the Pole; we never sent an expedition in that direction provided with the means of wintering and exploring at the proper season, consequently the Spitzbergen seas were abandoned at the most favourable season for exploration.

The author made a few observations as regards the adoption of Smith's Sound as a starting-point for making a sledge expedition to the Pole: it appeared to him to be one of the most dangerous places in the Arctic Sea. And as he holds to the belief that we can approach the Pole by ships *via* Spitzbergen for reasons before adduced, viz., that spaces of water will be found, this state of things would render it impracticable to make exploration by sledges from Smith's Sound.

He further added that the information to be sought for in making observations respecting the condition and phenomenon of the globe at its axis, will be the more valuable, according to the duration of time available for scientific research. He compared the advantages which would result from the visit of a ship to the Pole, with those afforded by small sledge party.

Regarding the speculation whether land will be found about the Pole, all the observations and facts before us tend to show that there can be no land of any extent; for at Parry's farthest north $82\frac{3}{4}^{\circ}$ N., he sounded the sea to 500 fathoms, but found no bottom. The large icebergs produced from the glaciers in Greenland are not seen north of Spitzbergen. We hear of no earthly débris, stones, or boulders being observed by the Spitzbergen voyagers lying on the ice-floes or fields. By the comparatively mild or modified severity of the Arctic climate at Spitzbergen 80° N., the isothermal curve of temperature, corresponding with that of South Greenland and Hudson's Bay, shows almost conclusively that there can be no extent of land near the Pole capable of bearing glaciers.

Should circumstances involve the necessity of spending a winter at Spitzbergen, either in Fair Haven or Hecla Cove, we can find perfect security for a ship, with an ample field of useful occupation for both officers and crew, in making observations and gathering information for scientific purposes, from the high latitude of 80° N. As the spring advanced, the pursuit of game would be a source of amusement and health.

That the North Pole may be reached by sea is the opinion entertained by many experienced Arctic navigators and eminent men of the past and present day, among whom are Parry, Beecher, Ross, Belcher; and General Sabine, one of the survivors of our discoverers in those seas, strongly advocates the attempt.

On the Seychelle Islands. By Lieut.-Col. LEWIS PELLY.

Shores of the Persian Gulf. By Lieut.-Col. L. PELLY.

Notes on Arabia. By Lieut.-Col. L. PELLY.

In this paper the author communicated some further details regarding Arabia, in addition to those he had already made public in the 'Proceedings of the Royal Geographical Society.' The most interesting related to the Selabah, Seleb, or Selaib tribe, who inhabit portions of the interior. On certain festivals, particularly on occasions of marriage and circumcision, they fix a wooden cross, dressed in red cloth, and adorned at the top with feathers, at the door of the person married or circumcised. At this signal the people collect together, and dance round the cross. The word *Saleb* means a cross; but some of the caste derive their name from *Es-solb-el-Arab*, i. e. from the back of the Arabs, meaning that they are the pure de-

scendants of the aboriginal Arabs. The Mohammedans, on the other hand, stigmatize them as outcasts. Those of the tribe who have immigrated into Nejed and other Mohammedan settlements, conform outwardly to the religious rites of the dominant creed; but in their own tents, and when alone, they do not conform. No intermarriage takes place between the Selaib and the Arabs. The Selaib are capital sportsmen; they live largely on venison, and wear a long shirt, coming down to the feet, of deerskin. But their ordinary diet is locusts and dates. They wander for pasturage for their sheep and camels during eight months in the year. They profess to reverence Mecca, but state that their own proper place of pilgrimage is Haran in Irak or Mesopotamia. It is said also that their principal people have psalms and other books written in Chaldean or Assyrian. They worship the Pole-star, which they call *Jah*, as the one immovable point which directs all travellers by sea or land. They reverence also a star in the constellation called Jedy, corresponding with Aries. In adoring either of these heavenly bodies, the Selaib stands with his face towards it, and stretches out his arms so as to represent a cross with his own body. They believe in one God, and pray three times a day—at sunrise, at the declension from the meridian, and at sunset. They are peaceful, and markedly hospitable, like all people who have nothing to give. The Selaib themselves assert that they are a tribe of Sabæans who emigrated to Nejed. The author stated that the Imaum of Nejed, who had received his mission so favourably, had been assassinated soon after his departure from Arabia.

On the Comoro Islands. By Lieut.-Col. L. PELLY.

The Comoros are a group of four islands lying between the northern extremity of Madagascar and the East African coast. The most northerly is Comoro proper, an island about thirty miles in length, with an average breadth of about ten miles. Nearest to this, and a little further south, is Mohilla, the smallest of the four. Johanna, lying south-east of Mohilla, and distant from it some thirty miles, is the second in respect of extent; and Mayotte, thirty miles south-east of Johanna, is third. In the year 1841 the French established themselves on the little island of Zaondzi, near Mayotte, gaining their position by espousing the cause of one of the contending chiefs, on the condition of his ceding Zaondzi to them. It is now fortified and furnished with an arsenal, and it was at one time planned to make Mayotte a military and naval position of the first class; but the plans seem to have been discarded since the revolution of 1848. Mayotte has reef-locked anchorages extending over a length of more than thirty miles; communication is kept up with Bourbon by means of a small steam schooner of war, and Col. Pelly found some thousand tons of coal, besides patent fuel, stored at Zaondzi. The staple product of Mayotte is sugar; if well cultivated the island might export from 15,000 to 20,000 tons per annum; but there is a great scarcity of labour. The population is stated to number about 7000 souls. The island of Johanna is a sultanat, without any direct relation with the other islands, the present chief being named Abdullah, the descendant of a family which has ruled the island for the last century. Johanna contains a population of 12,000, including aborigines, half-castes, slaves, and foreigners. A *lingua franca*, called the Johanna language, is current, but Kisuahili is also spoken. The Arabic character is used in writing, no matter what the language may be, even if English. The people profess the Mohammedan religion, and are apparently quite free from the vice of drunkenness. The climate is salubrious, sea breezes and frequent showers tempering the heat. The soil is composed of the detritus of volcanic rocks and humus. Coffee thrives excellently, and will probably form ultimately the staple product of the island. The trade of Johanna is at present not large, the total value of the past year's (1860) imports being about £4500, and it is carried on chiefly with Zanzibar and the French settlements at Mayotte and Madagascar. Mohilla is governed by a queen related to the royal family of Madagascar. The island has a population of about 4000 souls. Of all the Comoro group Comoro proper is the most remarkable for the magnificence and wildness of its scenery. From its surface rises an active volcano, 8000 feet in height, which frequently vomits forth streams of lava, which flood its flanks and form new promontories and islands in the surrounding ocean. When the English consul, Mr. Sunley, visited the island after an absence of four years, he found a lava reef three-

quarters of a mile in length jutting out near his old landing-place, and perplexing his topography. The principal town is Maroni, but the island is partitioned among many chieftains, who are jealous of their land and water holdings.

Ethnology of the Hindû-Chinese Nations. By Col. PHAYRE.

Notes on the Russian Frontiers in Central Asia.

By Sir H. C. RAWLINSON, M.P., F.R.S.

The author commenced by stating that the present boundaries of Russia in Central Asia were delineated with accuracy on the maps of Asia published by Messrs. Stanford and by Prof. Kiepert, of Berlin. He then gave a brief narrative of the successive encroachments of Russia in this direction. Formerly the frontier extended from the northern shores of the Caspian, by a long bend to the north, to the northern frontier of Chinese Tartary. Along this border was formed the Orenburg and Siberian line of outposts, and south of it, extending to the Khanats of Khiva, Bokhara, and Khokand, dwelt the numerous hordes of Kirghises on their steppes. In 1847 the Russians constructed here three forts to strengthen their hold on the region. The Kirghis steppe is traversed only by a few roads, the most important of which runs from Orsk, north of the Aral Sea, to the Jaxartes. With the exception of one part of it, over the Karakum sands, this route is well supplied with pasture, and the whole is traversable by wheeled carriages. By recent encroachments the Russian frontier is now extended to the Jaxartes; but the line as it at present stands is rather difficult to trace—at least that part of it which extends from Fort Perofski, on the Jaxartes, to the river Talas, including the new acquisitions of Turkestan, Chemkend and Tashkend, and even Russian officers do not know its exact course in its further continuation to the south of the Lake Issy-Kul. Their efforts have been directed to the connexion of the Issy-Kul line of forts with those of the Jaxartes, the result of which will be the absorption of the whole Khokand territory on the left bank of the Jaxartes. The advance of the Russians in this direction has been attended with great benefits to science and civilization; but although the fear of Russian invasion may be a chimera, it behoves us to consider what will be the political effect upon our own empire in India when there shall thus be a powerful Russo-Asiatic neighbour on its northern borders. Whilst the Russians have been advancing a distance of 1000 miles from north to south, our Indian empire has extended 1000 miles from south to north. The actual distance of our political frontier (the frontier of Thibet, a country under our influence) from the nearest point in Russian territory is now between 400 and 500 miles, that is, from Karakorum to the Thian Chan range; but our real frontier at Peshawur is above 1000 miles distant, according to the most recent itineraries of our agents who have traversed the intervening space. The most recent advance of Russia in Khokand has provoked the hostility of the neighbouring Khan of Bokhara, and it is within the bounds of probability that the forces of Russia and Bokhara are now in collision.

On a Recent Survey of the Chain of Mont Blanc.

By A. ADAMS-REILLY, B.A.

The author described the imperfect state of our knowledge with regard to the topography of the Mont Blanc range, and the motives that had induced him to construct, on his own surveys, an elaborate map, a large sketch of which was exhibited. The errors in the delineation of this and of other mountain-chains arose from the fact that they usually form the boundaries of countries, and the Government surveyors of each do not cooperate with each other, but carry their work simply to the watershed of the ridges. It thus frequently happens that the surveys of the two sides of a ridge are found, when compared, to contradict each other. Before the visit of Windham and Pocock, 1741, the valleys of Mont Blanc were unknown to the world, and the glaciers of the range were so erroneously delineated up to the year 1842, when Prof. J. Forbes commenced his observations on the Mer de Glace, that he found himself obliged to make an entirely new survey

of that glacier and its tributaries. This was the only portion of the chain accurately laid down when the Mont Blanc sheet of the Swiss Federal Survey came out in 1861, which, as the Swiss surveyors only gave, from their own work, the small portion lying within Swiss territory, filling in the rest from the Sardinian Survey, was found to be untrue to nature. The author commenced his surveys in 1863. The glacier system of Mont Blanc may be roughly said to be divided into three parts by two large clefts; that on the west being formed by the north and south glaciers of Miage, and that on the east by the glaciers of Argentière and Mont Dolent. In each case the two glacier-valleys advance from opposite sides deep into the heart of the chain, and their upper heads are only separated by rocky walls scarcely half a mile in thickness. The centre of the chain is occupied by an immense glacier-basin, which again is subdivided into three glaciers having but one common outlet, the Mer de Glace. From the point where it makes an abrupt turn to the north to return again on the other side of the Glacier de Miage, the backbone of the chain runs pretty nearly from south-west to north-west. At several spots, as, for instance, the Aiguille du Glacier, Aiguille Verte, and Mont Dolent, a number of ridges radiate towards the same point, culminating in a magnificent peak, and at others the main ridge thickens into an enormous mountain mass, like the Grandes Jorasses. The Swiss surveyors, in carrying their triangulation up to the eastern side of one of the ridges on the Sardinian frontier, which had been triangulated by the Sardinians on the western side, mistook the position, and inserted it on their map as a separate mountain-chain. In order to correct this it was necessary to annihilate four square miles of glacier, and to pull together into one, two mountains which had previously stood a mile and a half apart on the maps.

On the Flints of Pressigny le Grand.

By Professor STEENSTRUP and Sir J. LUBBOCK, Bart., F.R.S., Pres. Ent. Soc.

The authors related that the discovery of these flints was due to Dr. Leveillé, who had been induced, by the interest which the general subject had excited, to search for flint weapons in his neighbourhood. He was so fortunate as to find them in astonishing abundance, and the neighbourhood of Pressigny was evidently the site of several manufactories, as the distribution of the worked flints is very local. In one case they were found in abundance on one side of a little valley, while on the other side not one was to be seen. The "*livres-de-beurre*" and their chippings, at the manufactory of La Claisière, at least, were found to extend not more than 18 inches below the surface, and among them numerous fragments of charcoal were discovered. The authors took pains to set at rest all doubts regarding their being the refuse of a gun-flint manufactory. Gun-flints were first adapted to the muskets used by the French army in the year 1700, and they proved the much greater antiquity of the flint implements by finding several on excavating under the roots of an oak-tree, ascertained to be at least 400 or 500 years old. With regard to the age of the flints, the authors thought that there were not, as yet, any actual proof that the *livres-de-beurre* belonged to the age of the extinct mammalia, although other and probably older worked flints are found in the neighbourhood, which closely resemble those of the Palæolithic period.

Notes on the Aborigines of Formosa.

By R. SWINHOE, H.M.'s Consul, Formosa.

The approach to the *Kalee* savages, who inhabit a mountainous district in the southern part of the island of Formosa, is now comparatively easy, owing to the establishment, by the Roman Catholic Padre Fernando Sainz, of a small church and residence in a village of half-castes at the foot of the mountains, where he numbers some forty converts. The villagers to whom he preaches speak the Chinese dialect, with which he is acquainted, but he is now turning his attention to the *Kalee* language. In the villages adjoining the Christian village of *Bang-Kimsing*, are chiefly *Hakka* Chinese from North Kwang-tung, who are almost always at war with the *Kalees*. It is only therefore at night that the *Kalees* can be induced to come down to visit the priest. Mr. Edwards, an enterprising photographer, visited the village in company with the author, and took the portraits of two groups of these savages.

The complexions of the women are brunette, of lighter or deeper shade. The wild Kalee women are naturally good-looking, and are sought after by the Chinese of the eastern side of the island for wives; but the priest said it was common for them, after some years, to return to the wilds and pick up savage lords. In consequence of these intermarriages, Kalee features and type are seen to prevail amongst the ordinary Chinese population throughout Formosa; giving to the Formosan Chinese almost as distinct characteristics as a native of Amoy compared with a Cantonese. Many faces among the male Kalees reminded the author of the Tagals of Luçon. They wear turbans and loin-cloths of black material, and short jackets of yellow cloth. Their spear-handles are of bamboo, and their sword-scabbards painted red. The men are not tattooed, but the women are so across the back of the hand in lines. There is little room for doubting that the Kalee tribe are of Tagal origin; but there are other tribes inhabiting the mountains of Formosa of quite distinct race, the wildest of them being of dwarfed stature, and probably allied to the Negritos of the Andaman Islands; the author, however, as yet had not had an opportunity of seeing them.

On the Negro-European Dialects of Surinam and Curaçao. By E. B. TYLOR.

The original West African languages of the Negro slaves imported into America and the West Indies, have been almost totally replaced by broken-down dialects of the languages of their European masters. Two of these dialects, the Negro-English of Surinam and the Negro-Spanish of Curaçao, were examined by Mr. Tylor, with the view of testing, by a set of facts, the whole history of which happens to be known to us, the use and value of philology as an aid to ethnology. The Spaniards were superseded as the dominant class in the island of Curaçao by the Dutch. The effect of this change has been, not to supersede a broken-down Spanish dialect by a Dutch one, but merely to introduce a number of Dutch words into the Negro language, which still preserves its Spanish character. Thus, too, the Negro-English of Surinam did not lose its English character by the cession of the colony to the Dutch, but merely took in a number of Dutch words, the character of the language remaining English. Among the examples of the Surinam dialect, taken from the New Testament, translated by the Moravian missionaries, were the following:—"Dem hiti netti na ini watra; bikusi dem de fisiman," "Casting a net into the sea, for they were fishers." "*We ibriuan boen boom de meki boen vroektoe*," "Even so every good tree bringeth forth good fruit." In this latter example, *ibriuan* is English "everyone," and *meki* is "make," but *boen*, "good," is Spanish *bueno*, while *boom*, "tree," and *vroektoe* "fruit," are Dutch. It would seem at first sight that the fact of a West African Negro population speaking a language which must be classed as English, is evidence that language is not necessarily a proof of race at all. Mr. Tylor, however, called attention to the fact that, according to all experience, the descendants of the originally imported Negroes must have become mixed with English blood; and the same with the Negroes who adopted the language of their Spanish masters in Curaçao. He considered the quaint and rude dialects into which English and Spanish have been reduced in the mouths of the Negro slaves as good illustrations of a principle of much moment in the classification of races by language, namely, that though two peoples speaking kindred languages may be widely different in their descent, and therefore in their race as a whole, yet their use of languages derived from the same source is proof, at any rate, that men of the same race have been dominant among both peoples to a sufficient extent to impress their language upon them. And it is to be inferred from experience that such a state of things is always accompanied by the formation of a half-breed race, so that, at least to the extent of this minimum of mixture in blood, common language is a definite proof of common ancestry.

On the Origin of the Hungarians. By M. VAMBÉRY.

The author said the Hungarians belonged to the Altaic race, but there were many subdivisions which differed essentially; and it was important to know whether the Hungarians were of Finnish or of Turco-Tartar origin. To investigate such a ques-

tion there were three means—history, ethnography, and philology. The Greek and Gothic historical monuments relating to the first appearance of the Hungarians in the West were insufficient, and did not help to decide the question, but ethnology did render more assistance. The author then referred to some striking likenesses between the customs of Hungary and Tartary. Their greatest evidence they got from philology. In support of his view, the author quoted the analogy of grammatical forms between the Hungarian and Turco-Tartar languages, and then proceeded to make comparison in the lexicographical character of the languages. He thought both so strictly connected, that it was quite impossible to make the etymology of one without the other. There were many words of the earliest period of social state quite analogous, such as in the words tent, ox, hatchet, butter, cheese. The Hungarians were also connected with the ancient Persian civilization of Central Asia, which was proved by the many Persian words in her language. The ancient religion and earliest social conditions of the Hungarians were borrowed from the Parsee. There were also, he urged, elements of Turco-Tartar origin in the Persian.

On the City Life of Bokhara. By Dr. A. VAMBÉRY.

On the true Assignment of the Bronze Weapons, &c., supposed to indicate a Bronze Age in Western and Northern Europe. By THOMAS WRIGHT, F.S.A.

This paper was a criticism of the archaeological views of geologists, especially those of Sir John Lubbock as propounded in his recent work on Prehistoric Archaeology. The author gave his grounds of dissent from the division of early times into the three ages of stone, bronze, and iron, originated by Scandinavian authors. With regard to bronze, the corner-stone of this system of periods, the statement that “bronze weapons are never found associated with coins, pottery, or other relics of Roman origin,” was believed by the author to be founded on an imperfect acquaintance with the archaeological conditions of the problem to be solved. Bronze swords have been found with Roman remains, and the most ornamental Scandinavian bronze is simply a debased imitation of Roman Art.

ECONOMIC SCIENCE AND STATISTICS.

Address by The Right Hon. LORD STANLEY, M.P., F.R.S., the President of the Section.

LADIES AND GENTLEMEN,—In opening this Section, I need not trouble you with more than a few introductory remarks. It has been questioned how far such subjects ought to form part of the business of a strictly scientific association; and I do not think the question unreasonable, for it must be admitted that, while our political economy itself, in its present state, is rather a collection of practical maxims, supported by reason and tested by experience, than a science in the same sense as astronomy or optics are entitled to that name, the topics to which the statistical method is applicable are infinitely various, and have little in common except this one characteristic—that in every case we appeal either to the numerical test of accuracy, to figures, or else to fixed and recognized rules, which are assumed to have the same kind of certainty as prevails in physical science. How far that assumption holds good in practice, must depend on the judgment both of those who read papers, and of those who comment upon them. The truth is, in my opinion, our functions here are rather those of suggesting and stimulating, than of originating thought. Discussion, no doubt, we shall have, and in discussion new ideas are constantly generated, and new lights thrown upon previously unfamiliar topics; but it is not in crowded meetings, it is not in debating speeches, that any profound and original investigation can be carried on. Meetings like ours answer two purposes, apart from that of social enjoyment; one is the diffusion—not the

origination, but the diffusion—of ideas. Books and newspapers and reviews, no doubt, are the main agents for doing that work. Still it is, I think, indisputable that, as seeing is proverbially more impressive than hearing, so what we hear orally delivered makes upon us a stronger impression than that which lies on a printed page on which our attention may or may not dwell. The other is the stimulus given to inquiry by the mere fact of investigations of this kind, or the result of them, being brought prominently and conspicuously before the public. Men go home with their heads full of subjects on which they perhaps never thought seriously before; and since, as I believe, nothing once known is ever really forgotten—since an idea which has once found lodgment in the mind, though its presence there may long have been barren, and though we ourselves may have been unconscious of it, will often spring up into life after a long interval—it is difficult to determine what crop will not grow, sooner or later, out of the seed thus cast about apparently at random.

And now let me say a word as to the right application of the statistical method. To use figures rightly, assuming that they are accurate in themselves, is not so easy a matter as it is apt to appear. There are various fallacies into which unpractised statisticians fall, one or two of which may be worth noting. One, perhaps the commonest, arises from the use of too narrow a basis for calculation. To express my meaning,—given a certain class of men, between certain ages, as soldiers, agricultural labourers, artisans, and the like, the aggregate length of life among 10,000, or even among 1000 of them, will be practically a fixed quantity, you can determine it beforehand. But the length of any single life is of course uncertain; and if so few as 10, 20, or even 100 lives be taken, the element of chance, or what we call chance, is not sufficiently excluded, and a single exceptional case affects the general result. Another error, less easy to detect, arises from not taking into account all causes which affect the result. Thus, supposing that the question is, the effect produced by reduction of a tax in increasing consumption of the article taxed, it is natural, but a very obvious mistake, to urge, "*post hoc, ergo propter hoc*," to speak of that augmented consumption as arising solely from the reduction of duty which preceded it, ignoring the causes—such as general prosperity, and consequent augmentation of the consuming power; cheapening of means of transport, or lowering of the actual cost of production by mechanical improvements, or otherwise of the article consumed. Or, to take an illustration from a different class of subjects:—Suppose it is desired to ascertain the average mortality of a certain class; that for this purpose we take the mortality in that class during a certain number of years, and that, during one of those years, an epidemic of a destructive character has prevailed, you of course strike out that year from the series as unduly affecting the average. But, if you stop there, your calculation is again vitiated, though in a different manner, for it will almost always happen that an epidemic sweeps away a larger proportion of unhealthy than of healthy lives, and so the years succeeding their mortality, having been, so to speak, anticipated, are above the true average in point of health, and do not form a firm basis for a permanent calculation. Another variety of the same error, identical in principle, is when effect and cause are confounded. For instance, I have heard a sanatorist argue, with great general truth, in favour of model-lodgings in towns, and support his argument by pointing out the diminished rate of mortality in them, as compared with that of the same class outside. No one could dispute the general conclusion, but in fairness it should have been taken into consideration, as a qualifying proposition, that model-lodgings, by their reputation for superior cleanliness and healthiness, attract not the average, but the best men of the class for whom they are designed—that is, those whose chances of life are the best, independent of the room in which they are lodged. Hence involuntary exaggeration, by which a good cause could only suffer.

Another and perhaps simpler example is the existence of a hospital, or sanatorium, in an otherwise healthy locality. Unless that be allowed for, it is clear that the place in question will be credited with many deaths which are not due to it,—nay, this absurdity follows, that the more the spot is resorted to by invalids (Madeira would be a case in point) on account of its very healthiness, the higher its apparent mortality becomes. This last example is not without its practical importance, especially in cases of military mortality. It is obvious that, by a system of dis-

charging at once, or offering inducements for the retirement of men who are likely to become invalids, a fictitious appearance of healthiness in a camp or army may be produced, the diseases which arise there not being suffered to work out their natural result, and their existence, or rather the existence of causes predisposing to them, being thus effectively concealed. A third source of error, perhaps less material, but still worth notice, is that of confounding in one class facts not identical. For instance, the average death-rate of England is easily ascertained, but if you wish to apply that practically to a particular place or class, you must not take the figures as they stand. The death-rate of towns is not that of rural districts, the mortality of infants greatly exceeds that of adults, the term of life is shorter in the labouring than in the well-to-do classes. Age, class, and locality must be separately determined before you can arrive at an even approximately accurate conclusion. The figures, which serve for all collectively, precisely because they do so serve, are illusory if applied to any one of these in particular.

I mention such possible mistakes in order to show how utterly wide of the truth is the idea that to work by and with statistical calculations is a merely mechanical function, needing no ability beyond that of a careful clerk. They require common sense and vigilance against errors, like every other method of inquiry. Figures do not, indeed, deceive you, but, if you put them to a use they are not meant for, they will let you deceive yourself.

I suppose it is hardly necessary to remind you of the uses of the statistical method as applied to national affairs. If a man in private life finds his money going too fast, and wants to retrench, the first thing he does is to say, "I must keep regular accounts." So individuals keep diaries of particular matters in which they feel interested, not trusting to vague recollections, but setting down their notes day by day. Every person of observant habits, or engaged in any pursuit which requires accuracy, is in some sense a statistician; and it is hardly possible to over-rate the value of figures, partly as checking the universal tendency to exaggeration, not wilful, but a kind of mental illusion which operates whenever we are deeply interested—partly as giving precision to ideas which would otherwise remain floating in our minds in a vague, and therefore comparatively useless form. For instance, to say generally that a given trade or employment—that of a grinder or soldier, in the tropics—is unhealthy, conveys a very faint expression, and expresses our feelings but slightly. But put it in this way—that the average length of human life in some occupations is shorter by ten or fifteen years than that of an ordinary labourer—and not only habitual calculators, but the man himself, however ignorant or thoughtless he may be, is able clearly to realize the sacrifice he is making in going into that business. With regard to the question of drainage, of ventilation, of food, or use or abuse of strong drinks, it is the statistical test employed on a large scale which alone can be conclusive. I say on a large scale, for it is of the very essence of statistical inquiry that by dealing with masses it eliminates individual peculiarities. We reason back from the mass to the individual. The unit of the statistician, his typical or representative man, is the average man of many thousands. We are familiar with the effect on public health of the establishment of sanitary statistics. Let me point out one or two more instances in which figures form a part, and a very important part, of the diary of our national life. Take the Post Office returns, showing an increase of the correspondence as compared with the past, and the difference which exists at the present day in the amount of letter-carrying between one part of the country and another—say between the population of Ireland and that of London. Take the Registrar-General's returns of marriages, and note how the number of these, relatively to the population, rises or falls as the material condition of the masses is for the time better or worse. Take the annual returns of the Customs and Excise departments. Take our Census Abstract of the occupations of the people. Take our Criminal Statistics, a comparatively new department, and one probably still admitting of much improvement. You may read in these collectively the social and economical history of the age in which we live; and note everywhere the absence of mere chance. We speak of chance—it is a word we must use for convenience sake—but we really mean by it, not that the result of the thing discussed is in itself uncertain, but that some or all of the determining causes of such result are to us unknown. We imply, not the absence of a

law, but inevitable ignorance on our part of what the law is. When you find uniformity, or something which closely approximates to uniformity—as in the number of letters yearly posted without addresses, in the number of widows and widowers who marry, or in the number of detected offences of the same nature committed within the year—it is impossible not to be impressed, however trifling may be the illustration of them, with the permanence and steadiness of the laws which regulate our existence.

Now, is there any use in knowing that? I think there is. In the first place, no knowledge that bears upon human life is useless, even though we do not at the moment see the practical application to which we can put it. A discovery always turns to account in some way. The most important mechanical inventions owe their origin to purely mathematical theories which the authors of them never dreamt of so applying. In the next place, it is only by observing men in masses, and with the aid of all such helps to accuracy as we can command, that we can fairly appreciate the influence of general causes, whether material or moral, on individuals. Take a town in which a thoroughly good system of drainage has been established: you want to learn what has been the effect of that system on health. Question each person or each family separately, you will probably get very conflicting and dubious testimony; but register the deaths and causes of death, compare them with what they were before, and with similar returns in other places, and the decrease will give you at once a measure of what has been effected. And, lastly, of that large class of human evils which are reparable as well as preventible—evils affecting not life but property, or affecting life in its relation to property—there are very few to which the principle of insurance may not be applied. Now what does insurance mean? It is the opposite of gambling. The gambler, desiring to gain something that is not his, risks in return something of that which he actually possesses. The insurer, seeking to preserve that which he has, submits to a certain small fixed deduction, and thereby precludes the occurrence of a much larger possible loss. The one purposely increases the hazards of life, the other purposely diminishes them. Now if, as I believe to be indisputable, a sense of security is one of the first requisites both for material improvement and moral development, whatever creates or strengthens that sense of security is an element of human progress; and when a proprietor has guaranteed himself, according to the nature of his property, against fire, against shipwreck, against loss of stock by disease, or of loss by storm; still more, when the man who lives by his industry has secured himself, not indeed against premature death, but against that which to such persons having families is the sharpest pang of premature death, the dread of leaving unprovided for those whose existence is bound up with his own, it is difficult to estimate, by any tests or results that can be shown on paper, the amount of good which is practically effected; for that gain must be measured not by the number of persons actually saved from distress, but by the infinitely greater number saved from the apprehension of distress, the fear being often as bad as the thing feared. It is not easy to overrate the benefit which the modern practice of insurance has conferred and will confer upon mankind. And why, in opening this Statistical Section, do I refer to it? Because it is a practice founded in its very nature on statistical inquiries, and which without such inquiries could not have existed.

It remains only to speak of a few desiderata—a few things wanting to be done. In England our chief defect is the absence of agricultural statistics. That is a question which has been long before Parliament. The difficulty of collecting such facts as are really wanted does not seem to be great; but between prejudices on both sides, statisticians asking too much, and farmers unreasonably jealous of giving any information, the thing has always fallen through. I hope in that respect the new Parliament may be more fortunate than its predecessor. I ought also to note as inconvenient in the highest degree the excessive complication of our English weights and measures. They are probably by far the worst in Europe in that respect. But I note that fault in no very sanguine spirit as to a remedy being applied. Our national peculiarities, a great indifference to simplicity and uniformity, and a dislike to changing anything to which we have once become accustomed, and the total absence of any strong interest in the subject, except among a few individuals, place reform in this matter wholly beyond my expectations. Parliament, no doubt,

has legalized the use of the metric system—a step which is very well as far as it goes, but which really, for all practical purposes, leaves matters where they were. Compulsion is not to be thought of; and, on the whole, I strongly suspect the next generation will do exactly what I am doing now—admit the inconvenience, and say it can't be helped. Even with regard to the decimalization of coinage, which is a matter really in the power of the Government, I do not think we are likely soon to see anything done; and it is obvious that weights and measures cannot be changed without a general feeling of willingness among the people to give up those existing and adopt the substitutes. It is more satisfactory to look to the operations of the Board of Trade. Their little yearly volume, called “The Statistical Abstract,” is full of useful information, packed into the smallest compass, and arranged with a careful rejection of trifling and unimportant details. I should be glad to see the scope of that publication extended, and references added, so as to include the principal results of all official inquiries, showing in a tabular form where fuller details on the subjects dealt with may be found.

I think it is also worth considering, since every European Government now takes a decennial census, whether some understanding may not be come to amongst leading States, to frame their inquiries as nearly as may be in the same way, and to publish them in the same order and form, so that for purposes of comparison they may be at once and easily available; for, notwithstanding local and national divisions—differences of languages, of institutions, and of race—Europe inclines more and more to become, in its general habits of thought and action, one community; and Napoleon's phrase, that a war in Europe is a civil war, like most sayings of great men, becomes truer and more applicable, not less so, by the progress of time. I do not know that it would serve any useful purpose if I were to anticipate the contents of papers that may be read in this Section. They will be many, various, and I hope interesting, and ought to lead to useful discussion. Let me only offer to those who take part in our discussions one or two suggestions. The first is, time runs fast. You can say all you have got to say in a few words, if you will think it over beforehand. It is want of preparation, want of exact thought, that makes diffuseness. Again, we don't want preambles or perorations. We are not a school of rhetoric; and in addressing an educated audience a good deal may be taken for granted. Lastly, we only wish to get at the truth of things. All ideas are welcome, but mere verbal criticism is of no value to us. Some of the topics with which we shall deal may perhaps have a political bearing, and in that case I hope and expect that they will be dealt with in a strictly impartial and scientific spirit.

On the Division of Labour. By W. B. ADAMS.

On the Duration of Life, the Prevailing Diseases, and the Causes of Death, of Pottery. By J. T. ARLIDGE, M.B.

On the Municipal Expenditure of the Borough of Birmingham.
By THOMAS AVERY.

The intention of this paper was to submit a brief history of the Municipal Expenditure of Birmingham, with the view of comparing the progress of the town in wealth and population with its increase in Taxation, Expenditure, and the amount of its public debt.

Previously to the incorporation of the Borough, the town was governed by Commissioners, under different Acts of Parliament; the last of which was obtained in the ninth year of the reign of King George IV., and was entitled “An Act for better paving, lighting, watching, cleansing, and otherwise improving the town of Birmingham, in the county of Warwick, and for regulating the police and markets of the said town.”

The Commissioners, by an Act of Parliament passed in the year 1851, transferred to their successors a public debt of about £112,250, and an equivalent in valuable property of £196,291.

A Table is annexed of the financial results of the concluding five years of the separate government of the Commissioners, from 1835 to 1839. In all of the fol-

lowing calculations, it has been found convenient to give the population of the present limits of the *borough*, as nearly as it could be ascertained, but the Table of the expenditure of the Commissioners has been formed upon the population of the *parish*.

The population of the decennial periods has been taken in both cases from the Census Tables, and that of the intermediate years has been ascertained by a percentage thereon.

TABLE A.

| Year. | Population. | Yearly payments. | Amount per head. |
|-------|-------------|------------------|------------------|
| | | £ | s. d. |
| 1835. | 159,802 | 26,847 | 4 5 |
| 1836. | 163,366 | 27,240 | 4 4 |
| 1837. | 166,966 | 33,209 | 5 3 |
| 1838. | 170,704 | 30,216 | 4 8 |
| 1839. | 174,493 | 31,154 | 4 9 |
| 1840. | 178,456 | 35,140 | 5 1 |
| 1841. | 182,922 | 36,939 | 5 3 |
| 1842. | 187,435 | 40,660 | 5 6 |
| 1843. | 192,102 | 53,849 | 6 7 |
| 1844. | 196,884 | 78,775 | 9 3 |

During the next ten years, the population and expenditure increased as in Table B.

TABLE B.

| Year. | Population. | Yearly payments. | Amount per head. |
|-------|-------------|------------------|------------------|
| | | £ | s. d. |
| 1845. | 201,789 | 58,445 | 7 6 |
| 1846. | 206,827 | 67,697 | 7 7 |
| 1847. | 211,991 | 83,987 | 9 2 |
| 1848. | 217,284 | 70,363 | 7 6 |
| 1849. | 222,709 | 70,610 | 7 6 |
| 1850. | 228,259 | 98,836 | 9 10 |
| 1851. | 232,841 | 101,717 | 9 9 |
| 1852. | 238,615 | 104,527 | 8 9 |
| 1853. | 244,574 | 123,379 | 10 2 |
| 1854. | 250,683 | 131,723 | 10 6 |

Continuing these calculations for the ensuing ten years, there is the same large increase in the numbers of the population, but accompanied by a disproportionate augmentation of the public expenditure.

TABLE C.

| Year. | Population. | Yearly payments. | Amount per head. |
|-------|-------------|------------------|------------------|
| | | £ | s. d. |
| 1855. | 256,943 | 135,283 | 10 6 |
| 1856. | 263,363 | 123,814 | 9 5 |
| 1857. | 268,695 | 142,909 | 10 7 |
| 1858. | 275,406 | 137,644 | 10 0 |
| 1859. | 282,288 | 135,053 | 9 7 |
| 1860. | 289,340 | 145,310 | 10 0 |
| 1861. | 296,076 | 104,183 | 7 2 |
| 1862. | 303,777 | 155,644 | 10 3 |
| 1863. | 310,966 | 157,996 | 10 2 |
| 1864. | 318,732 | 172,211 | 10 10 |

Taking the average population and amount of expenditure, we have the following results for three decennial periods:—

TABLE D.

| Year. | Average amount of expenditure per head. |
|---------------|---|
| | s. d. |
| 1835 to 1844. | 5 6 |
| 1845 to 1854. | 8 10 |
| 1855 to 1864. | 9 10 |

Though the population had increased from 159,802 in 1835 to 318,732 in 1864, the increase in the cost of local government in the same period had been so much out of proportion thereto, that, whilst it was 4s. 5d. per head in 1835, it had become 10s. 10d. per head in 1864. This grave fact eminently deserves the most anxious consideration of the Members of the Council of Birmingham, and of all who wish well to Municipal Institutions. For many years this town has enjoyed a remarkable measure of almost uninterrupted prosperity, which has enabled the Burgesses to support this heavy expenditure with comparative ease; but should we again be visited with bad times, it is to be feared that it would be felt as a grievous calamity. It is, however, satisfactory to observe, that for the last several years the expenditure per head has been nearly stationary, and it may be hoped that it will now begin to diminish.

To give a correct view of the magnitude and variety of the subjects comprehended within the jurisdiction of the Corporation, statements are appended of the income and expenditure for the year 1864, from which it will be perceived that several expensive items are included in the present municipal government, such as public baths and parks, free libraries, and a borough cemetery, which did not come within the scope either of the proceedings or the powers of the Commissioners.

(The Tables referred to give the detailed receipts and expenditure for the year 1864, but are unavoidably omitted from want of space.)

TABLE E.—Giving the amount of the nett unpaid balances of the public debt, and the annual charges thereon.

| Year. | Debt. | Annual interest and repayment of principal. |
|-------|---------|---|
| | £ | £ |
| 1852. | 297,950 | 17,886 |
| 1858. | 437,286 | 30,611 |
| 1864. | 638,303 | 49,192 |

From this statement it will appear that the increase has been as follows:—

TABLE F.

| | 1852. | 1864. | Increase. | Percentage increase. |
|---|-----------|-----------|-----------|----------------------|
| Population..... | 238,615 | 318,732 | 80,117 | 34 per cent. |
| | £ | £ | £ | |
| Rateable value ... | 679,750 | 981,500 | 301,750 | 45 " |
| Income (Table K). | 2,080,817 | 3,199,298 | 1,118,481 | 54 " |
| Debt | 297,950 | 638,303 | 340,353 | 114 " |
| Interest and re-
payments on
account of debt. } | 17,886 | 49,192 | 31,306 | 175 " |

The property now in the possession of the Corporation, with its approximate value, and also of the important public works and improvements executed by that body, amounts to £894,064, including property of the value of £196,241 received from the Commissioners.

In further confirmation and illustration of the increased and increasing pressure of the public debt, and the large proportion of the general revenue which it is gradually absorbing, the following Table is submitted. As a convenient and easily

understood arrangement, the receipts of the improvement account only are furnished, that being the chief and most legitimate source of income; but the payments on account of the debt comprehend the whole of the charges thereon; that is to say, those of the municipal and street improvement accounts are also included, and the same principle is observed throughout the calculation:—

TABLE G.

| Year. | Receipts from improvement account. | Charges on account of debts. | Income from the improvement account. | Proportion of the improvement account absorbed by charges on account of debt. | Proportion of the improvement account available as general income. |
|-------|------------------------------------|------------------------------|--------------------------------------|---|--|
| | £ | £ | £ | s. d. | s. d. |
| 1852. | 54,849 | 17,886 | 36,963 | 0 8 | 1 4 |
| 1853. | 54,501 | 18,786 | 35,715 | 0 8 | 1 4 |
| 1854. | 60,944 | 21,698 | 39,246 | 0 8 | 1 4 |
| 1855. | 67,272 | 25,941 | 41,331 | 0 9 | 1 3 |
| 1856. | 67,220 | 27,945 | 39,275 | 0 10 | 1 2 |
| 1857. | 75,353 | 28,511 | 46,842 | 0 9 | 1 3 |
| 1858. | 79,260 | 30,611 | 48,649 | 0 9 | 1 3 |
| 1859. | 78,610 | 33,707 | 44,903 | 0 10 | 1 2 |
| 1860. | 82,547 | 34,107 | 48,440 | 0 10 | 1 2 |
| 1861. | 55,783 | 28,143 | 27,640 | 1 0 | 1 0 |
| 1862. | 83,561 | 43,072 | 40,489 | 1 0 | 1 0 |
| 1863. | 87,607 | 45,793 | 41,814 | 1 0 | 1 0 |
| 1864. | 89,638 | 49,142 | 40,446 | 1 1 | 0 11 |

As a collateral branch of this subject, it may not be inappropriate to furnish a Table of the amounts levied by the overseers of the poor, and also of the proportion of them absorbed by the borough rate for municipal purposes, and which is entirely under the control of the Corporation. It is much to be desired that this singular anomaly should be speedily abolished, that the Corporation should be authorized to collect the whole of its own rates, and that the entire system of municipal taxation should be simplified and consolidated.

TABLE H.

| Year. | Total amount of poor-rate collected. | Proportion paid to corporation for borough rate. | Proportion available for relieving the poor. | Per head. |
|-------|--------------------------------------|--|--|-----------|
| | £ | £ | £ | s. d. |
| 1849. | 70,073 | 26,690 | 43,383 | 5 2 |
| 1850. | 70,503 | 38,757 | 31,746 | 3 8 |
| 1851. | 73,193 | 39,572 | 33,621 | 3 10 |
| 1852. | 58,095 | 35,615 | 22,480 | 2 6 |
| 1853. | 51,298 | 30,218 | 21,080 | 2 4 |
| 1854. | 88,860 | 34,247 | 54,613 | 5 11 |
| 1855. | 72,971 | 22,521 | 50,450 | 5 4 |
| 1856. | 88,956 | 39,072 | 49,884 | 5 2 |
| 1857. | 88,303 | 37,914 | 50,389 | 5 1 |
| 1858. | 91,078 | 43,584 | 47,494 | 4 9 |
| 1859. | 81,479 | 35,505 | 45,974 | 4 6 |
| 1860. | 71,123 | 30,881 | 40,242 | 3 11 |
| 1861. | 85,986 | 36,443 | 49,543 | 4 8 |
| 1862. | 125,688 | 39,868 | 85,820 | 7 11 |
| 1863. | 103,820 | 46,376 | 57,444 | 5 2 |
| 1864. | 118,712 | 47,139 | 71,573 | 6 4 |

TABLE J.—Showing the rateable value of the property of the Borough from 1855 to 1864.

| Year. | Rateable value. |
|-------|-----------------|
| | £ |
| 1855. | 739,750 |
| 1856. | 762,510 |
| 1857. | 841,330 |
| 1858. | 853,340 |
| 1859. | 864,490 |
| 1860. | 880,980 |
| 1861. | 899,230 |
| 1862. | 827,730 |
| 1863. | 959,590 |
| 1864. | 981,500 |

The annexed Table K describes the amounts assessed to property and income tax; it affords information on the progress of the town in wealth and prosperity.

TABLE K.

| Year. | Population. | Amount of assessment of property and income tax. | Per head. |
|-------|-------------|--|-----------|
| | | £ | £ s. d. |
| 1850. | 228,259 | 1,814,508 | 7 19 0 |
| 1851. | 231,841 | 1,904,826 | 8 3 7 |
| 1852. | 238,615 | 2,080,817 | 8 14 5 |
| 1853. | 244,574 | 2,170,722 | 8 17 6 |
| 1854. | 250,683 | 2,409,549 | 9 8 11 |
| 1855. | 256,943 | 2,459,137 | 9 11 5 |
| 1856. | 263,363 | 2,396,452 | 9 2 0 |
| 1857. | 268,695 | 2,568,607 | 9 11 2 |
| 1858. | 275,406 | 2,614,951 | 9 9 11 |
| 1859. | 282,288 | 2,662,221 | 9 8 7 |
| 1860. | 289,340 | 2,692,572 | 9 6 2 |
| 1861. | 296,076 | 2,923,829 | 10 1 3 |
| 1862. | 303,377 | 3,006,445 | 9 18 2 |
| 1863. | 310,966 | 3,049,580 | 9 16 1 |
| 1864. | 318,732 | 3,199,298 | 10 0 9 |

The amount of national taxation does not necessarily form any part of this inquiry, but it may nevertheless be instructive to notice it, and the following Tables are therefore subjoined, which have been taken from a valuable article contributed by Professor Leone Levi to the Journal of the Statistical Society:—

TABLE L.—United Kingdom; Population and Taxes, 1801 to 1858.

| Year. | Population. | Taxes. | Per head. |
|---------------|-------------|--------------|-----------|
| | | | £ s. d. |
| 1801 to 1810. | 17,000,000 | 57 millions. | 3 7 1 |
| 1811 to 1820. | 20,000,000 | 74 " | 3 14 0 |
| 1821 to 1830. | 22,500,000 | 58 " | 2 11 6 |
| 1831 to 1840. | 25,500,000 | 51 " | 2 0 9 |
| 1841 to 1850. | 27,000,000 | 55 " | 2 0 8 |
| 1850 to 1858. | 28,000,000 | 60 " | 2 2 1 |

TABLE M.—Population and Wealth.

| Year. | Population. | Wealth. | Per head. |
|-------|-------------|----------------|-----------|
| | | | £ |
| 1801. | 16,000,000 | 1800 millions. | 112 |
| 1811. | 18,000,000 | 2100 „ | 116 |
| 1841. | 27,000,000 | 4000 „ | 150 |
| 1858. | 29,000,000 | 6000 „ | 206 |

TABLE N.—United Kingdom; Population and Income.

| Year. | Population. | Income. | Per head. |
|-------|-------------|---------------|-----------|
| | | | £ s. d. |
| 1800. | 16,000,000 | 230 millions. | 14 7 0 |
| 1841. | 27,000,000 | 450 „ | 16 15 0 |
| 1858. | 29,000,000 | 600 „ | 20 15 0 |

In examining the figures of the three latter Tables, we discern one of the chief causes of the public tranquillity and contentment which now so happily prevail. Associated with this marvellous development of national wealth there is a diminished taxation—in other words, there is less to pay and more to pay it with, so that the burthen of it is easily supportable as compared with the pressure of former years, and it is much to be desired that the same results should be sought and achieved by our local municipal government.

It has been seen that the expenses of the Corporation for 1864 were 10s. 10d. per head, and as in addition thereto the cost of relieving the poor in the same year was 6s. 4d., it follows that we have altogether the very serious expenditure of 17s. 2d. per head. The introduction of railways and of steam navigation, and the removal of some of the restrictions upon trade, are bringing us more and more into competition with the cheap labour and lightly-taxed populations of other countries; and an economical administration of the public affairs of the town, or the absence of it, may therefore exercise an important influence upon the permanent welfare of this busy and industrious community.

In bringing this paper to a close, an attentive consideration of the subject appears to lead to the following conclusions:—

1. That the progress of the town in wealth and population has been enormous, but that the amount of taxation and of municipal expenditure has increased in still greater proportions.

2. That the public debt especially appears to have excessively increased, owing to the rapidity with which public works and various improvements have been executed, thereby imposing heavy burthens upon the present generation of rate-payers.

3. That it would have been desirable to have omitted some of the least important of these undertakings, and to have extended the others over a longer period of time, and that for the future they should either be suspended altogether, or proceeded with more slowly and deliberately.

4. That an increased taxation does not appear to have materially interrupted the progress and prosperity of the town, but that in the event of any continued depression of trade, it would be almost insupportable by large numbers of the rate-payers, and that therefore the utmost vigilance and caution should be constantly exercised to control and diminish its amount.

Social, Educational, and Religious Position of the Working Population of South Staffordshire. By the Rev. W. J. BAIN.

Every one who has travelled through South Staffordshire has been struck with the appearance of the district and the people. The view from any of its central eminences is weird and striking. The mighty furnaces belching forth fire and

smoke, the great stacks of tower-like chimneys which everywhere meet the eye, the general blackness of the surface, the rolling clouds of smoke which shroud all, the glimmer of pools of water breaking through the dense masses of habitation everywhere apparent, the tumultuous roar which comes surging upward, all impress the gazer deeply. Underneath that thick smoke-cloud and among those leaping furnaces, toils and lives and dies as sturdily a population as any in England.

Of the moral, social, educational, and religious condition of this population, the most contradictory accounts are given; but it was not the purpose of this paper to balance or contrast contradictory statements. The paper especially regards the working classes, and was a review of the influences which have affected this district in the past and still affect it—on the one hand to degrade, on the other to restore and elevate.

The first point noticeable is that of *the circumstances of the growth of the populations of the towns of South Staffordshire.*

From this point of view much of the present misery and degradation is intelligible.

Most of the towns have a very old history; some are called old even before the Norman era. They seem to have been generally agricultural. The population was small. With the development of the mineral wealth came a great increase in population, till from the quiet country village you find yourself in the midst of the noisy, dirty town of some 20,000 inhabitants. In 1727 Dr. Plot found twelve pits open at Bilston; now he would find some 300. Now with such a rapid increase, and that just at the period of the Church's and the country's greatest apathy as to the secular and religious education of the people, it seems manifest that the district must have been utterly neglected, its opportunities of education wholly inadequate to the requirements. Thus the vices which have made the Black Country so notorious, were developed without check.

The *brutality and propensity to violence* imputed to the people are regarded as much exaggerated in the statements of casual observers. At the same time the very nature of South Staffordshire work tends to foster a pride in physical strength, and where ignorance and habits of intemperance prevail this will tend to brutality and cruelty.

The *habits of drunkenness and extravagance* which do so very much disgrace the population, present us with a very important item in the social position. Here also certain circumstances of the work and the position of the working man throw a light on the evil and its remedy. There is a strong conviction amongst puddlers, millmen, and men of that class, that they cannot do without much beer during their "heats." The effect of this continual recurrence to beer during the interval of work before a fierce fire is readily understood. The whole constitution becomes sodden with drink. Then, the workman has no out-of-doors charm of scenery to fall back upon when his day's toil is over. The exigencies of mining operations and the acid furnace-smoke have destroyed the green and pleasant face of nature. There is but the public-house, or home, or some rough game. Add further that the workman earns in many cases very high wages; this to natures uncultivated, only gives a scope to all propensities to excess. Habits of intemperance are only too prevalent. Beer-houses are multiplied beyond all proportion. Men are paid in public-houses. Funerals, accidents, are only occasions of indulgence. Some workmen have part of their wages in an allowance of beer.

It need hardly be said that licentiousness and immorality are fearfully prevalent, these are usual concomitants of intemperance; but it is notable how very much concubinage is the custom, and how little regard is paid to the obligations of marriage.

The *propensity to gambling* seems to have a strong hold on the population.

The *ignorance of the population*, especially in its lower section, demands more attention.

Ignorance in South Staffordshire has been something appalling, and is still very great. The last generation had but few facilities compared with the present; the children of most miners can now be educated where the habits of the parents do not interfere, but persons above forty years of age are frequently incapable of reading. The facilities of education have increased tenfold within a generation; still, great

as is the change, the ignorance of the young of both sexes is very great. Of collier lads, about one-half can read at all, and that lamely; of lads in "works," reports of commissioners, committees, and examiners speak in terms which make us aware how little has yet been done, notwithstanding the immense efforts being made. Attendance for education or on religious worship seems to be so lax that it counts for almost nothing. If this be so in cases where facilities are afforded, for there are schools attached to the respectable "works," what shall we say of that proportion of the population utterly neglected or found out only by the town missionary and the ragged school? When out of seven in favourable circumstances one only can read, when such lads know nothing of Christ or the Crucifixion, or a future state, cannot repeat the Lord's prayer, what shall we say of the others?

In tracing the causes of this ignorance, the hindrances to education, we must point to the *employment of young persons at a very early age* in nail-making, brick-fields, on pit banks and elsewhere. The expression of opinion of a great employer is quoted advocating such employment of children and denouncing government interference. The same person objected to all education of colliers or the working class, as tending to unfit them for their work. These sentiments date back only three years, yet are now fast disappearing. The children, thus denied the opportunity of learning in their early life, must grow up rude and ignorant. Statistics of schools confirm the view thus given. The proportion of children found in schools in various districts after ten years of age is as follows:—South Staffordshire, 16 per cent.; North Staffordshire 32; North and East Ridings of Yorkshire, 32; Halifax, worsted manufacturing district, 40. The children thus debarred the benefit of school, are found in engine-houses, iron-works, japan-shops, brick-fields, and elsewhere, doing work which men ought to do or machinery. The connexion of ignorance with pauperism and crime comes out clear enough in the statistics. In Stafford gaol, out of 23 juvenile offenders, 19 were from the Black Country, and of those only 9 could read when committed. At the Saltley reformatory, out of 42 lads there for various crimes, 23 were from South Staffordshire, and of these only 3 could read when committed.

The *employment of females in work utterly unfitted for them* is another item in the social status. South Staffordshire has a bad notoriety in this matter. The labour on the pit bank or in the brick-field may not be unhealthy, but it is demoralising. No female can grow up, under such circumstances, with true womanly delicacy or fitted for domestic life. Statistics gathered from various sources prove that the result of such a condition of things is a frightful amount of immorality and general debasement amongst the girls so employed.

A further element in the social degradation of the people, and an obstacle to all improvement, is found in the *wretched dwellings of the people*. The houses of the poor are but too often the property of the poor, and are thus destitute not only of all convenience, but outrage all decency—are hotbeds of disease, physical and moral. The tumble-down shanties of South Staffordshire have become a standing disgrace; but much is now being done towards their improvement.

Passing over many points of interest, this is noted as a last, and not least, important item—the fact that *very few of the great employers live amongst their people or mingle much with them*.

This practice of absenteeism is growing; nor do many of the proprietors take the trouble to keep themselves pleasantly in the minds of their people. A piece of land laid out for recreation would cost them little in any district, and would be a noble boon. From these and other circumstances the author rates South Staffordshire lower than similar districts in England and Scotland.

Yet there are signs of rapid improvement, and agencies are at work which are rapidly changing the faces of things. The New Congregational Chapel at Bilston stands on the spot where the crowd gathered of old to see the bull baited, and thus many a vile custom has yielded to the influence of education and religion. The agencies most effectual in such a district are those which partake of the nature of guerilla warfare. Evening classes, ragged-schools, working men's clubs, lectures, books of pleasant reading, short, pithy—these are the things which must influence educationally the working population. The town missionary is the most efficient pioneer, religiously. Much of such agency is now at work; the thing is how to

extend and further organize it. "The Association for the Promotion of Adult Education" is a capital example of what may be done in that direction. Temperance societies have done much and are doing much; but a quieter mode of action would be advisable. Provident societies are increasing, and have now generally adopted the principle of holding their meetings apart from the public-house.

Old vile habits are certainly disappearing; more literature is circulated and of a far better tone; the people themselves seem awake to their deficiencies and eager to retrieve. The last strikes and lock-outs showed what even ten years had done in diffusing information, quickening intelligence, and raising almost a new order of workmen. We may hope that in time, though we cannot free South Staffordshire from smoke and grime—therein is its wealth—still it may be said of the district, having regard to its moral purity, it is "black but comely."

The following Table exhibits the statistics of population at various periods, and the relative facilities of secular and religious instruction. The Table is necessarily imperfect: there is great difficulty in getting correct statistics in these matters, a difficulty arising from various causes. The centres of population change rapidly in this district; the Table, however, is sufficient for our purpose, and trustworthy in the main.

| Town. | Population
in 1811. | Population
in 1862. |
|------------------------------|------------------------|------------------------|
| Wolverhampton township | 14,836 | 49,985 |
| Dudley parish | 12,000 | 45,000 |
| Walsall | 12,300 | 37,762 |
| West Bromwich | 5,687 | 41,774 |
| Wednesbury | 5,372 | 20,000 |
| Bilston | 9,649 | 25,000 |
| Willinghall..... | 3,523 | 18,000 |
| Darlaston | 4,812 | 18,000 |
| Kingswinford | 8,267 | 35,000 |
| Tipton | 8,407 | 28,870 |
| Smethwick township | 1,597 | 14,000 |
| Sedgley parish | 13,937 | 35,000 |
| Cannock | 1,500 | 7,000 |
| Wednesfield | 1,248 | 8,553 |

Of this population one-fifth is engaged in the mines, a third in the manufacture of iron, less than a half in the branches of industry where skilled labour is demanded. But the Table is every year becoming less and less trustworthy, so rapidly does population change its centres of increase in this wondrous district. Cannock, for instance, will in all probability quickly be lost in the amazing extension of its hitherto unknown neighbour, Brownhills. There collieries are being opened, and fresh ground occupied with astonishing rapidity, and Cannock Chase is threatened with absorption in the insatiable demand for coal.

Now let us place side by side with this arranged representation of the vast aggregation of population the following statistics of the educational and religious facilities:—

| | 1814. | 1864. | | 1814. | 1864. |
|---|-------|-------|---|-------|-------|
| WOLVERHAMPTON. | | | DUDLEY. | | |
| Public day-schools | 3 | 23 | Public day-schools | 3 | 14 |
| Sunday-schools..... | 6 | 30 | Sunday-schools | 3 | 20 |
| Literary, scientific, and other
institutes | 1 | 5 | Mechanics' and other institut ^s .. | 0 | 3 |
| Protestant churches | 2 | 10 | Protestant churches | 1 | 4 |
| Dissenting chapels | 4 | 18 | Dissenting chapels | 2 | 11 |
| Catholic chapels | 1 | 2 | Catholic chapels | 1 | 2 |
| Other places of worship | 0 | 3 | Other places of worship | 0 | 4 |

| | 1814. | 1864. | | 1814. | 1864. |
|--------------------------------|-------|-------|---------------------------------|-------|-------|
| WALSALL. | | | DARLASTON. | | |
| Public day-schools | 2 | 8 | Public day-schools | 0 | 4 |
| Sunday-schools..... | 3 | 15 | Sunday-schools..... | 3 | 7 |
| Mechanics' and such institutes | 0 | 3 | Mechanics' and such institutes | 0 | 1 |
| Protestant churches | 1 | 4 | Protestant churches | 1 | 3 |
| Dissenting chapels | 2 | 15 | Dissenting chapels | 2 | 4 |
| Catholic chapels | 1 | 1 | Catholic chapels | 0 | 0 |
| Other places of worship | 0 | 2 | Other places of worship | 0 | 0 |
| WEST BROMWICH. | | | KINGSWINFORD. | | |
| Public day-schools | 2 | 16 | Public day-schools | 1 | 10 |
| Sunday-schools..... | 3 | 28 | Sunday-schools..... | 3 | 20 |
| Mechanics' and such institutes | 0 | 4 | Mechanics' and such institutes | 0 | 1 |
| Protestant churches | 1 | 5 | Protestant churches | 2 | 8 |
| Dissenting chapels | 2 | 20 | Dissenting chapels | 2 | 12 |
| Catholic chapels | 0 | 1 | Catholic chapels | 0 | 0 |
| Other places of worship | 0 | 2 | Other places of worship | 0 | 0 |
| WEDNESBURY. | | | TIPTON. | | |
| Public day-schools | 1 | 8 | Public day-schools | 1 | 11 |
| Sunday-schools..... | 4 | 12 | Sunday-schools..... | 3 | 21 |
| Mechanics' and such institutes | 0 | 1 | Mechanics' and such institutes | 0 | 1 |
| Protestant churches | 1 | 4 | Protestant churches | 1 | 4 |
| Dissenting chapels | 3 | 10 | Dissenting chapels | 2 | 20 |
| Catholic chapels | 0 | 1 | Catholic chapels | 0 | 1 |
| Other places of worship | 0 | 2 | Other places of worship | 0 | 0 |
| BILSTON. | | | SMETHWICK. | | |
| Public day-schools | 1 | 9 | Public day-schools | 1 | 5 |
| Sunday-schools..... | 2 | 15 | Sunday-schools..... | 1 | 8 |
| Mechanics' and such institutes | 0 | 1 | Mechanics' and such institutes | 0 | 1 |
| Protestant churches | 1 | 5 | Protestant churches | 1 | 4 |
| Dissenting chapels | 1 | 12 | Dissenting chapels | 0 | 4 |
| Catholic chapels | 0 | 1 | Catholic chapels | 0 | 1 |
| Other places of worship | 0 | 1 | Other places of worship | 0 | 1 |
| WILLENHALL. | | | SEDGLEY. | | |
| Public day-schools | 0 | 7 | Public day-schools | 0 | 13 |
| Sunday-schools..... | 3 | 13 | Sunday-schools..... | 3 | 28 |
| Mechanics' and such institutes | 0 | 3 | Mechanics' and other institutes | 0 | 1 |
| Protestant churches | 1 | 4 | Protestant churches..... | 1 | 4 |
| Dissenting chapels | 2 | 13 | Dissenting chapels | 2 | 25 |
| Catholic chapels | 0 | 1 | Catholic chapels | 0 | 1 |
| Other places of worship | 0 | 1 | Other places of worship | 0 | 1 |

Statistics of Pneumonia.

By Professor JOHN H. BENNETT, M.D., F.R.S.E., of Edinburgh.

The author, in the first place, pointed out the great difficulty of determining the exact value of any particular treatment in a disease, and then described a Table he had constructed, giving in columns the sex, age, previous health, the day when first seen after the commencement of the disease, the day of convalescence, period of convalescence, pulse, respirations, complications, treatment, with observations of all the cases of pneumonia which had entered his wards, in the Royal Infirmary of Edinburgh, since the year 1848. These were 129 in number, all treated by restoratives. There were only four deaths, or 1 death in 32 $\frac{1}{4}$ cases, and in these the fatal result was not owing to the pneumonia but to other diseases which complicated it. With regard to treatment therefore these four cases are excluded.

Of the 125 remaining cases 85 were males, and 40 were females. The average age was 30 $\frac{1}{4}$ years; 105 cases were simple, and 20 were complicated. The average duration of the disease in the former, when single, was 13 $\frac{2}{7}$ days, when double 16 $\frac{3}{4}$ days. The duration of residence in the hospital of the complicated cases was 21 $\frac{2}{7}$ days, that of the uncomplicated cases was determined by the nature of the complication.

Dr. Bennett compared these results with those of other hospital physicians, in which various treatments had been practised in pneumonia, confining his remarks, however, to such as were drawn from an equal or a larger number than his own, and from the whole inquiry derived the following conclusions* :—

"1. That an extreme antiphlogistic treatment has always been attended with a large mortality, amounting to 1 death in 3 cases; but that when modified in various ways—that is, by diminishing the amount of lowering remedies, selecting cases, or by the cases being those of young and vigorous subjects—the mortality varies from 1 death in $4\frac{1}{2}$ to 1 death in 13 cases. When one-half the cases are those of children, or persons below twenty years of age, and the lowering treatment slight, the mortality diminishes to 1 death in 28 cases.

"2. That a treatment by large doses of tartar emetic has been accompanied by a mortality varying from 1 death in $4\frac{1}{2}$ to 1 death in $9\frac{1}{2}$ cases.

"3. That a dietetic or expectant treatment has been followed by a mortality varying from 1 death in $7\frac{1}{4}$ to 1 death in 10.9 cases. In children, according to Barthez, the mortality is almost *nil*.

"4. That the results of a mixed treatment, in which various remedies have been employed, according to the nature of the case and the stage of the disease, are a mortality varying from 1 death in $3\frac{1}{2}$ to 1 death in $13\frac{3}{4}$ cases.

"5. That a tonic treatment with iron and copper, according to Kissel, was attended with a mortality of 1 death in 22 cases.

"6. That a treatment by stimulants, according to Todd, was followed by a mortality of 1 death in 9 cases.

"7. That the restorative treatment of the author having been attended, in the worst point of view, by a mortality of only 1 death in $32\frac{3}{4}$ cases, is the most satisfactory yet published. But when it is considered that the 4 deaths resulted from pathological complications unconnected with the pneumonia, it may be said to render the mortality in true cases of pneumonia *nil*.

"8. That 105 uncomplicated cases, occurring consecutively in the clinical wards of the Royal Infirmary when under my care, during a period of sixteen years, should all have recovered, is a fact which can only be ascribed to the nature of the treatment, as is shown by contrasting that treatment with others in which a lowering, expectant, mixed, or specific practice was tried.

"9. That just in proportion as other treatments approach the restorative principle, and avoid lowering the system, so much the greater is their success. It will further be observed that although a direct lowering practice has been avoided, if the diet had been restricted, or opium, digitalis, alcohol, or other drug largely given, capable of weakening the system and diminishing appetite, no great advantage has been arrived at. So that—

"10. The variations which appear to follow the same treatment by different physicians are explicable by the amount of weakness in the patient, or circumstances favouring weakness in the treatment, such as low diet, bleeding, tartar emetic, &c. It follows that supporting and restoring (not stimulating) the nutritive powers of the system, and avoiding all weakening remedies, ought to constitute the practice in pneumonia."

On the Statistics of Crime in Birmingham, as compared with other large Towns.

By J. THACKRAY BUNCE, F.S.S.

For the sake of brevity the state of crime in Birmingham was given only at three triennial periods—1858, 1861, and 1864. The results of the examination were given in seven Tables appended to the paper. The figures throughout were taken from the official volume of 'Judicial Statistics.'

Table I. showed the number of houses of bad character reported to the police.

Table II. the number of the criminal classes, in their recognized divisions of known thieves, receivers, prostitutes, suspected persons, and vagrants—as estimated by the police.

* See the Restorative Treatment of Pneumonia, by J. Hughes Bennett. 8vo, Edinburgh 1865.

Table III. the number of indictable offences committed, with the number of persons apprehended, discharged, and committed for trial.

Table IV. the number of persons proceeded against summarily, with those discharged, convicted, and fined.

Tables V., VI., and VII., the nature of the indictable offences committed, the principal offences under the class of summary procedure, and the previous character (as returned by the police) of the persons dealt with under both heads.

The following is a summary of the first four of these Tables :—

| | 1864. | 1861. | 1858. |
|--|-------|-------|-------|
| Total criminal class..... | 3190 | 3271 | 6415 |
| Total houses of bad character | 906 | 907 | 844 |
| Total number of indictable offences | 752 | 836 | 2659 |
| Total number of summary offences | 8420 | 6905 | 3285 |
| General total of indictable and summary offences . | 9172 | 7741 | 5944 |
| Total persons apprehended and summoned | 9018 | 7578 | 4329 |
| Total number discharged | 4138 | 3001 | 2320 |
| Total number convicted, or committed for trial .. | 4880 | 4553 | 2009 |

The discrepancy between the criminal class in 1858 and 1864 is accounted for by the adoption of a better mode of reckoning them by the police : in the former year they were merely estimated, in the last-named year the name of every person belonging to the criminal class (that is, known to be living by crime or to be a professional vagrant) was actually written down, and care was taken to see that no name appeared twice in the list. The following Tables show the general results of a comparison of all England, Birmingham, Manchester, Liverpool, Leeds, and Sheffield for the year 1864 :—

| Places. | Popula-
tion,
1861. | Crimi-
nal
classes. | Disre-
putable
houses. | Indict-
able
offences. | Sum-
mary
offences. |
|------------------------|---------------------------|---------------------------|------------------------------|------------------------------|---------------------------|
| England and Wales..... | 20,066,224 | 101,303 | | 51,058 | 440,913 |
| Birmingham..... | 296,076 | 3,190 | 906 | 752 | 8,420 |
| Manchester | 338,346 | 3,106 | 1111 | 6,623 | 11,327 |
| Liverpool | 443,874 | 3,175 | 1518 | 4,326 | 36,448 |
| Leeds | 207,000 | 1,588 | 313 | 489 | 6,201 |
| Sheffield | 185,000 | 433 | 161 | 414 | 5,091 |

In regard to the class of offences committed, the following Table shows the comparative criminality of Birmingham and the four other towns above named :—

| Indictable offences. | Birming-
ham. | Man-
chester. | Liver-
pool. | Leeds. | Sheffield. |
|-----------------------------|------------------|------------------|-----------------|--------|------------|
| Murder | 2 | 3 | 9 | | 1 |
| Attempts to murder, &c..... | 31 | 31 | 148 | 7 | 13 |
| Burglary and housebreaking. | 289 | 502 | 305 | 67 | 34 |
| Highway robbery..... | 18 | 171 | 47 | 26 | 9 |
| Larcenies | 225 | 5286 | 3215 | 313 | 224 |

Under the head of summary offences, the following comparative result is obtained :—

| | Birming-
ham. | Man-
chester. | Liver-
pool. | Leeds. | Sheffield. |
|--|------------------|------------------|-----------------|--------|------------|
| Assaults | 1918 | 2357 | 3,461 | 1816 | 981 |
| Drunk and disorderly | 1078 | 3587 | 14,002 | 1815 | 1038 |
| Offences by publicans | 459 | 855 | 933 | 91 | 224 |
| Offences against Local Acts. | 1695 | 145 | 8,726 | 835 | 787 |
| Malicious damage | 199 | 246 | 637 | 164 | 181 |
| Larceny | 1044 | 1145 | 2,238 | 414 | 349 |
| Offences against Vagrancy Act | 706 | 1127 | 1,236 | 342 | 516 |
| Offences against Weights and
Measures Act | 278 | 138 | 118 | 6 | 298 |

The subjoined Table shows the number of the criminal classes, the indictable offences, the summary offences, and of both combined, in proportion to population:—

| | England,
1 in | Birming-
ham,
1 in | Man-
chester,
1 in | Liver-
pool,
1 in | Leeds,
1 in | Sheffield,
1 in. |
|---|------------------|--------------------------|--------------------------|-------------------------|----------------|---------------------|
| Indictable offences;
crimes reported . . . | 394·96 | 393·72 | 51·08 | 102·6 | 423·3 | 446·86 |
| Summary offences;
persons proceeded
against | 45·5 | 35·16 | 29·87 | 12·17 | 33·38 | 36·33 |
| Indictable offences and
summary offences
taken together . . . | 40·8 | 32·28 | 18·85 | 10·88 | 30·94 | 33·6 |
| Criminal classes; re-
puted number . . . | 198·08 | 92·81 | 108·83 | 103·3 | 130·35 | 427·25 |

An additional Table was put in for the information of the Section:—

Indictable Offences—Crimes reported, Apprehensions, and Number of Persons Discharged and Committed.

| | Offences. | Appre-
hended. | Dis-
charged. | Con-
victed. | Police to
population. |
|-------------------|-----------|-------------------|------------------|-----------------|--------------------------|
| Leeds | 489 | 414 | 77 | 337 | 1 in 787 |
| Sheffield | 351 | 332 | 120 | 212 | 1 in 801 |
| Birmingham | 752 | 598 | 157 | 431 | 1 in 785 |
| Liverpool | 4,326 | 2,125 | 1213 | 912 | 1 in 431 |
| Manchester | 6,623 | 1,407 | 775 | 632 | 1 in 504 |
| All England | 51,058 | 28,734 | 8700 | 20,004 | 1 in 906 |

From this Table it appears that the percentage of *apprehensions to reported offences* is as follows:—All England, $56\frac{1}{4}$; Birmingham, 79; Manchester, 21; Liverpool, 49; Leeds, $84\frac{3}{4}$; Sheffield, $94\frac{1}{2}$.

The *percentage of committals to apprehensions* is as follows:—All England, $69\frac{1}{2}$; Birmingham, 72; Manchester, 45; Liverpool, 42; Leeds, 81; Sheffield, $63\frac{3}{4}$.

On the Practical Advantages of the Metric System of Weights and Measures.
By F. P. FELLOWS, F.S.S.

This paper proved the practical advantages of the metric weights and measures over those of the English System. First, in the great economy of time in calculation, through the metric system being decimal; and secondly, the facilities

afforded through its measures of weight, capacity, square and cubic measure being all directly and decimally derived from the metre (the measure of length).

The paper was elaborately illustrated by diagrams, and numerous practical examples were given in proof of the great advantages of the system. To estimate the number of figures that would be saved in consequence of the metric system being decimal, the author stated that, "To judge of this advantage it will not do to take any particular example, for particular examples may be found in favour either of the English or the Metric System, or even in favour of the old Roman numerals; since CDM each expresses by one sign the quantity which in Arabic numbers must be expressed by three or four signs, thus, 100, 500, 1000. It will therefore be necessary to enter into some general calculation as to the number of figures required under each system, and to set down and carry out a regular series of figures in addition, multiplication, subtraction, and division, in order to see with which of the two systems the advantage lies. I take the weights, and begin with addition. I proceed with the metric system, and write down consecutively every weight that can be expressed, proceeding by grammes from 1 to 1024 grammes. 1024 items can be expressed, and to express them either in grammes, decihecto-, and kilogrammes, exactly the same figures, and therefore the same number of figures are required—the number is 2986.

"I proceed now to set down 1024 items in the English system, from the half drachm (the approximate equivalent of the gramme) to 1 lb. 15 $\frac{3}{4}$ ounces. The figures I must set down are—

| | |
|-------------------------|------|
| For the fractions | 1024 |
| For drachms | 1384 |
| For ounces..... | 1384 |
| For pounds | 512 |

Total figures required for the English weights. . 4304

or nearly 50 per cent. more than are required for the metric system.

"This is, however, only writing down data. Suppose we begin to add up the items in each system, we shall find the gain to the metric system enormous. I begin by adding 1 and 2 grammes, then 1, 2, 3 grammes, and so on; adding up every sum from one gramme till I have added from 1 to 31 grammes.

I have to set down before I add up..... 758 figures; and
The sums of these would take 83 "

Making the metric total 841

"Now I proceed to add up the English weights from half a drachm to 1 oz. (a similar number of items to the metric).

I have to set down before I add up 1027 figures,
When added up, the number of figures required to express the
sums in drachms is 92 "
But the sums of these drachms have to be brought in ounces and
pounds by calculation, and each addition involves a sum in
long division, which again involves multiplication and sub-
traction, and the number of figures I require to set down for
these calculations is 4096 "
To express the final result of my additions in pounds, ounces,
and drachms, I have to set down 89 "

Making a total (English) of 5304

Against a total (metric) of 841

or six figures English for one figure metric.

"Were we to strike off the figures required for the fractions in the English system altogether, still the English system would take 4277

"While the metric system would require but..... 841
or five figures English to one figure metric.

"In subtraction, multiplication, and division, the advantage of the metric system is still greater. In calculations of length, capacity, square and cubic measure, the proportion in favour of the metric system would be less than 5 to 1 in some cases, and in others much greater.

"The next advantage of the metric system arises from all its weights, measures of capacity, square and cubic measure being directly and decimally derived from the metre, and consequently being directly and decimally related one to the other." (Numerous tables were exhibited to illustrate this.)

The author then entered into some elaborate calculations to show that the universally received English equivalent of the metre was incorrect (notwithstanding that it had been sanctioned and adopted by the Royal Society, by a Royal Commission appointed to investigate the matter, and by the Houses of Lords and Commons), therefore the given English equivalents of all the weights and measures of the metric system were false. The author showed by demonstration that the absolutely correct English equivalent of the metre was 1 metre = 39·370387542944176 (38024691) inches [38024691 being a recurring series of decimals], say 1 metre = 39·37039 inches; whereas the universally received equivalent is 1 metre = 39·37079 inches. He pointed out that this error was increased in a square measure by the square of the error; and in measures of weight, capacity, and cubic measure by the cube of the error, since all metric weights and measures are derived from the metre by squaring and cubing. He showed that this error was far too great to be allowed to remain uncorrected, and gave several instances in which it would partly account for certain apparent discrepancies in terrestrial and astronomical measurements in different countries, stating, as a familiar illustration, that this error would make a difference of about 1000 miles in the given distance of the sun from the earth.

The author proceeded: "A Bill was lately passed by both Houses of Parliament, making legal in this country the use of the metric system of weights and measures. Attached to this Bill was a table or schedule which professed to give the metric equivalents of the English weights and measures; which equivalents are declared by the Bill to be binding on all traders using the metric system. Not only was this schedule founded on the incorrect datum that 1 metre = 39·37079 (the correct datum being 1 metre = 39·37039), but it did not harmonize even with its own datum. According to this Bill, a dekametre, that is 10 metres, or 100 decimetres, or 1000 centimetres, or 10,000 millimetres, if reckoned from the Government schedule,

as a dekametre, is a certain quantity;
if as 10 metres, is a second different quantity;
if as 100 decimetres is, a third quantity;
if as 1000 centimetres, is a fourth quantity;
if as 10,000 millimetres, a fifth quantity.

So that we have five different English equivalents given to represent the same measure, not one of which quantities is correct after all.

"For measures of surface, a hectare, that is 10 dekares, 100 ares, or 10,000 centiares if reckoned from the Government schedules tables as,

a hectare, is one quantity;
in dekares, is another quantity;
in ares, is a third quantity;
in centiares, is a fourth quantity

not one of which quantities is after all correct.

"For measures of weight, a myriagram, which is equal to 10 kilograms, or 100 hectograms, or 1000 dekagrams, is according to the Government schedule (when brought into English quantities), if reckoned as a myriagram, one quantity; if in kilograms, a second different quantity; if in hectograms, a third different quantity; if in dekagrams, a fourth different quantity; not one of which is correct.

"I fear that this Bill with this schedule may prove worse than useless, and it is only because I believe that it will be very mischievous, and may lead to endless litigation, and prevent the metric system ever taking root in this country, that I reluctantly raise my voice to endeavour to stop its action, and get it amended before it has done any serious evil. Indeed, in disputed cases, were I judge, I should not

know how to give a decision, as there is nothing in the Bill to say whether dekametres, metres, centimetres, &c. are to be calculated from, should any dispute arise.

"In illustration of the evils that may occur from this, a trader's yearly purchases of goods bought and sold by length, such as cloth, silk, satin, &c., are, say, £389,000. He hopes to make a clear gain (after paying every expense of salaries, rents, taxes, interest, &c.) of £1000 a year, which we will say he would do were the schedule of metric and English equivalents correct. Now, accordingly as he reduces his quantities from English into metric lengths, and *vice versa*, and buys and sells and reckons in dekametres, metres, centimetres, &c., though he has done exactly the same business, and bought and sold at exactly the same nominal price, yet by using the Government schedule he may actually find his net profit vary from £400 to £1600 per year. His net profit may vary (solely from the incorrectness of the schedule) as follows. It may be £400, or £420, or £435 16s., or £436, or £700, or £702, or £702 2s., or £710, or £1000, or £1282, or £1282 18s., or £1290, or £1300, or £1564, or £1565, or £1580, or £1600. To explain this more fully, say that 3940 inches of best broad gold lace are sold to A, B, C, and D as 100,000 millimetres (which equivalent is correct according to the schedule). I buy this from A, B, C, and D, but as 100,000 millimetres are equal to 10,000 centimetres, and these latter, according to the schedule, are equal to only 3937 inches, I only pay for 3937 inches instead of 3940. Thus in buying I gain 3 inches of gold lace through the schedule being incorrect.

"Now in selling I just reverse the process, and sell only 3937 inches as 10,000 centimetres, which, according to the schedule, is likewise incorrect. These 10,000 centimetres, according to the schedule, would also be exactly equal to 100,000 millimetres; so that in selling I gain 3 inches. Suppose the average price (quoted in English quantity) of the gold lace were £1 per inch; then

| | |
|--|--------|
| I buy 100,000 millimetres (3940 inches in reality) for | £ 3937 |
| And sell 10,000 centimetres (or 3937 inches) for.... | 3940 |
| <hr/> | |
| Thus gaining 3 inches and | 3 |
| Three inches being worth £1 each would be..... | 3 |
| <hr/> | |
| Total gain | 6 |

"On the other hand, I might have lost £6 instead of gaining it, or a difference of £12 might be made for or against me.

"In conclusion, I would strongly urge the advisability of investigating and correcting the inaccuracy of the English equivalent of the metre, and the rectification of the Government metric schedule before any further legal steps are taken to promote the metric system in this country."

Intercommunication between Railway Passengers. By G. B. GALLOWAY.

On the Means of saving Life from Buildings which may be on Fire.
By G. B. GALLOWAY.

Suggested Improvements applicable to the City of London and other large Towns, to improve Health and preserve Life. By G. B. GALLOWAY.

Statistics of the Small Arms Manufacture of Birmingham.
By J. D. GOODMAN.

Prior to the close of the 17th century, at which time Macaulay states that the population of Birmingham was only 4000, England obtained her supplies of arms from the continent. In 1689, by the direction of William III., an opportunity was given to the manufacturers of Birmingham to produce the flint-lock gun then in use. The first trial of the skill of the Birmingham men having resulted satisfactorily, an order was afterwards transmitted to five manufacturers to provide 200 Snaphance muskets per month, for which they were to receive, on delivery of each

hundred muskets, 17s. each, ready money, in one week after delivery in the Tower of London, and that they were to be allowed 3s. for the carriage of every one hundred-weight. This document bears date 5th of January, 1693. There is little or no information as to the progress of the manufacture till the commencement of the present century, when the military records denote the capabilities of the trade at that period. The following is the system at present pursued in carrying on this manufacture in Birmingham at the present time. The manufacture of the various parts of the gun, as barrel, lock, &c., are distinct branches. These several parts are collected by the manufacturer, known as the gun-maker, and by him are set up. The chief branches are:—Stock-making, barrel-making, lock-making, furniture-making, oddwork-making; and for military guns there are in addition, bayonet-making, sight-making, rammer-making. The stocks are of two kinds—beechwood and walnut. They are brought to Birmingham, cut from the plank into the form of the gun. Beech-stocks are grown in this country, chiefly in Gloucestershire and Herefordshire. Walnut-stocks are, with few exceptions, imported from Italy and Germany. On reference to the Directory of the present year, we find 599 names of manufacturers engaged in the different branches of the trade. The list of workmen employed estimates the total number at 7340. Of these 3420 are engaged in producing the materials, the barrel employing 700, the lock 1200, the bayonet 500, and so on. Setting up these materials into guns employed 3920 men. Of these the three chief branches are the stockers, screwers, and finishers. Each of these branches, with its subbranches, is estimated to employ 1000 men. The outworking system leads to the employment of a considerable number of young boys. No very correct estimate can be given of the rate of wages earned by the workmen in the gun-trade. During the past ten years there is little doubt but that the wages earned in this trade have probably exceeded those in any other. It is a very common practice in many of the branches for a workman to employ several assistants, whether working in the factory of his employer or as out-door worker. Strikes have occurred in the gun-trade, but happily not frequently. The gun-makers engaged in the military arms trade are associated together, one object being the regulation of wages to be paid to workmen. The men, in like manner, act together, the respective leading branches having their own organization. Masters and men each know the strength of the other, and have, on the whole, so arranged their mutual dealings as to avoid disputes. The Birmingham workmen are much more highly paid than those of Belgium and France. This low price of labour gives our Belgian rivals a great advantage; on the other hand, the better paid and better fed English workman can accomplish an amount of work far in advance of his Belgian workfellow; and the English manufacturers possess a further advantage in the more extended application of machinery, the use of which in Liège is discouraged by the cheap rate at which hand labour can be obtained. The Birmingham gun-makers have long been aware that a more extensive use must be made of the advantages which they possess, and this has led to the erection in Birmingham of an establishment for the manufacture of guns by machinery, on the interchangeable principle. We must give America credit for the introduction of this system. It was from thence it was brought into this country. The total number of processes under which an Enfield musket of the pattern 1853 undergoes is upwards of 600. Guns made by this system will interchange; that is, that any part of one gun will fit another. The factory of the Birmingham Small Arms Company is now in working operation. The system is there carried out in its full integrity. It has been planned on a scale to produce 1000 guns per week. There are upwards of 300 machines at work, but at present it has not reached its full power. The number of guns now made there is about 500 per week. The proving of barrels was first provided for by a charter granted by Charles I. to the London gunmakers. No public proof-house existed in Birmingham till 1813, when an Act of Parliament was obtained giving the necessary powers. A second Act was obtained in 1815, which remained in force till 1855, when the inventions of modern days rendered the establishment of new regulations necessary. By these regulations the security of the user was greatly improved. Under this Act the gun-trade is recognized as an associated body, to which all are entitled to belong who carry on the trade within ten miles

of the Borough of Birmingham, and who are rated to the poor at not less than £15. A fee of a guinea is paid annually on registration. The trade is required to meet on the 9th of March in each year, when they elect the managers of the Proof House. The total number of the guns and pistols proved in England during the period 1855–1864 was 6,116,305. Of this number there were proved at the Birmingham Trade Proof House, 3,277,815; at the Government Proof House in Birmingham, 978,249 (these last represent military guns made for the English service); at the London Proof House, 1,355,139; and at the Enfield Factory, 505,102. The Enfield Factory has only been in operation seven years. The average annual production will thus be—Birmingham Trade Proof House, 327,781; Birmingham Government Proof House, 97,824; London Trade Proof House, 135,513; Enfield Proof House, 72,154; making a total annual production for the whole of England of 633,272. As near as can be estimated, the number of small arms manufactured in Birmingham and elsewhere, for the Americans during the last four years, make a total number of 1,078,205, Birmingham supplying 733,403; London, 344,802. During the last ten years the total production of England was, after deducting the number of arms made at the Enfield Factory, 5,611,203. The production of the Liège trade during the same ten years was 6,842,264, or something more than 1,000,000 in excess of our make. It must be understood, however, that while the aggregate number produced in England is less than that of Liège, the aggregate value of the British arms is greater. The Belgians make a very large number of pocket-pistols at 1s. 0½d. to 1s. 11d. each pistol. In the ten years the number of pocket-pistols proved was 2,305,176—more than one-third of the entire make of Liège. In the English returns we have only 588,477 pistols, or little more than one-tenth, and none of these are sold at anything like the prices of the common pistols of Liège. As the demand for English work runs on superior qualities, the English makers have never attempted to make pistols of this very low class. The following statement will show the number of guns made and exported during the ten years, 1855–1864:—Number of guns made in England for ordinary trade, 3,822,457; of this number England exported 2,685,309; number of guns made in Belgium for trade, 5,390,675; number assumed to be exported by Belgium, 3,760,450; declared value of Belgian exports, £4,743,296; value of each gun, £1 5s. 2d. The arms manufactured by the English trade for Government use are estimated at £3 each. This is somewhat below the real value, but it will be near enough for the present purpose. These data will give us the following results as the value of the production of the two trades during the ten years 1855 to 1864 inclusive: Belgium, number of guns at 25s. 2d. each, 6,842,265; total value of Belgian guns, £8,609,849. England, number of guns at 33s. 10d. each, 4,632,954; value of ditto, £7,837,409. Number of guns at £3 each, 978,249; value of ditto, £2,934,747. Total value of English guns, £10,772,156. Although the value of our trade is thus shown to be more than equal to that of the only source of supply which at all approaches us in the extent of manufacture, it is manifest that the Birmingham gun-trade must be on the alert if it is to maintain its ground. To contend against the cheap labour of Liège is not an easy task. The establishment of the machine factory, it is hoped, is a step in the right direction. It will secure for the town the trade in the highest class of military work, which otherwise would have gone to its competitors. Excessive prices for labour are still paid in certain branches of the work, particularly when sudden pressure comes upon the trade. A more uniform rate of wages would benefit all parties; the master would feel more confidence in tendering for contracts at moderate rates, and the workmen would secure more regular employment.

Statistics of the Post-Office Savings' Banks. By ALFRED HILL.

The good effected by the Savings' Banks on the old principle, was limited by their fewness (only 683 in the United Kingdom), by their want of security (as proved by several failures), and by the short periods in the week during which they were kept open. As the Post-Office Savings' Banks have been well described in print*, this paper is confined to some special facts relating to their progress, for

* See 'Her Majesty's Mails.' London: Sampson, Son, and Co., 1864; and the 'Edinburgh Review' of July 1864.

which I am indebted chiefly to the kindness of Mr. Scudamore, the Assistant Secretary to the Post Office.

The following Table shows statistically the progress of the Post-Office Savings' Banks from their commencement in September 1861 to the 31st of August 1865:—

| Banks open. | | Amount of
Deposits. | Withdrawals. | Accounts
opened. |
|------------------------|------|------------------------|--------------|---------------------|
| | | £ | £ | |
| From Sept. 16, 1861, { | | | | |
| to Dec. 31, 1861 .. } | 1679 | 167,530 | 6,759 | 24,826 |
| 1862 | 2535 | 1,947,139 | 431,878 | 178,495 |
| 1863 | 2991 | 2,651,209 | 1,027,154 | 319,669 |
| 1864 | 3080 | 3,350,000 | 1,834,849 | 470,858 |
| June 30, 1865 | 3101 | 1,734,474 | 1,113,028 | 534,242 |
| Aug. 1865 | 3256 | 727,060 | 359,927 | 557,909 |
| | 3256 | 10,577,412 | 4,773,595 | 557,909 |

It will be observed that there are now 3256 Post-Office Savings' Banks (or nearly fivefold the number of the old Savings' Banks), and they are to be found in almost every town, and in every populous district. Of the money deposited, a large portion would certainly never have been placed in the old banks.

By the Postmaster-General's Report for 1864, it appears that at the opening of the Post-Office Savings' Banks in September 1861, there were in the United Kingdom 1,609,103 depositors in the old banks, whereas in March 1864 the depositors in both descriptions of Savings' Banks numbered in the aggregate 1,887,510, showing an increase in two years and a half of 17 per cent.

The average amount of each deposit diminished down to June last, since which time it has risen nearly to its original amount. The amount of each deposit is smaller in the Post-Office Savings' Banks than in the old ones, owing to the former being constantly open, while the latter usually transact business only once a week, or even once a fortnight, and the new banks are more brought home to the depositors' doors. The rise in the amount of each deposit was caused by the closing of the old Savings' Bank at Canterbury, and the transfer of its deposits to the Post Office.

The average amount of each withdrawal increases as deposits accumulate, and the average amount to the credit of each depositor increases steadily but slowly; slowly, because the great number of new accounts constantly being opened keeps down the average. This amount includes the interest due on the 31st December last; for interest is computed and added to capital at the end of every year. It is estimated that at the end of this year there will be 600,000 depositors in the Post-Office Banks owning £6,500,000 or £6,600,000.

The recent Act enabling deferred annuities and life assurances to be purchased through the Post-Office Savings' Banks cannot fail to be very beneficial to the poorer classes.

Besides providing for the investment of their savings, the Post-Office Banks give to persons of small means the accommodation afforded to the wealthier classes by ordinary banks, viz., a place of security for the amount kept for current expenditure. I am acquainted with a lady of very reduced means living on a small annuity, who, until the Post-Office Savings' Bank was established in her neighbourhood, used to be kept in a constant state of anxiety lest her half year's income should be stolen in the small houses wherein she was compelled to board.

In conclusion, it should be mentioned that statements, to the effect that the Savings' Bank duty is imposed on Postmasters without additional remuneration, are untrue, as a special allowance is made to each, dependent upon the amount of business done by him.

Statistics of the Benefit Building and Freehold Land Societies of Birmingham.
By G. J. JOHNSON.

Commencing with the statement that since the year 1842 nearly £2,500,000 had been paid by the working and lower section of the middle classes in Birmingham into such societies, the writer proceeded to explain four Tables illustrating the paper. Table I. gave a list of all the societies enrolled under the Building Societies' Act (1836) since the year 1842, when the first Society in Birmingham was formed under such Act. The number so enrolled was only two. The early societies were all formed on the "terminating" principle; most of the later ones (twenty-eight out of thirty-five) on the "permanent" principle, the details of which were explained at length. Table II. stated the results of the societies which had either terminated successfully, or been wound up without loss, from which it appeared that about £77,858 had passed through such societies. Table III. gave a list, so far as could be ascertained, of the societies which had ended in loss to the members; and it was remarked how small a proportion the unsuccessful societies bore to the others both in number and in the actual amount of business done. Table IV. contained the statistics of the nineteen existing Building and Freehold Land Societies of Birmingham, by which it appeared that these societies had received in the aggregate £2,242,968; that their present members numbered 11,193; the amount now due from borrowing members on mortgage was £539,732; and the amount due to investing members was £438,043, exclusive of £60,000 due to persons not members who had lent money on deposit at interest. The details of the working of both Building and Land Societies were then explained in reference to both classes of members, investors and borrowers; and the paper concluded as follows:—

"There is one question which has forced itself upon the attention of all engaged in the working of these societies, and that is, whether the time has not arrived for altering their legal status altogether. I have no wish to raise legal questions here, but it is not a legal but an economical question, whether societies having an income, as many of the larger Birmingham societies have, from £50,000 to £100,000 a year, ought not to have the advantages of corporate existence as may now be enjoyed by any seven persons who choose, by subscribing a memorandum of Association for one share of £1 each, to form a 'Joint Stock Company Limited.' No one can read the Act of 1836 without noticing that from the preamble declaring 'that it was desirable to afford encouragement and protection to societies to assist the members thereof in obtaining a *small* freehold or leasehold property;' down to the last clause the whole scope of the Act is utterly inadequate to the present condition of these societies. One instance will suffice. It is the theory of the Act that a Building Society is a small Friendly Society, the members of which will meet once a week or fortnight. Accordingly, it provides that a general meeting of the members may be called by a notice read at two such meetings. There are, at least, six societies in Birmingham with 1000 members and upwards—one with more than 3000. These members pay their subscriptions fortnightly, quarterly, or yearly; and when they go, or more often send to the office for that purpose, it is no more a meeting than the shareholders going or sending to pay their calls at a bank is a shareholders' meeting. The facts have outgrown the theory on which the Act was constructed. The consequence has been that more than once very improper rules have been made at meetings, called in the Act of Parliament mode, which were necessarily unknown to all the members, except the half-dozen interested in the object on which the meetings were called.

"What is wanted is a recognition that these societies are no longer small friendly societies, but are large investment associations, and are therefore entitled to become incorporated companies."

Statistical Data in relation to the Representation of the People.
By PROFESSOR LEONE LEVI.

On the proposed Extension of Government Administration to Railways.
By T. DE MESCHIN, LL.D.

On the Past and Present Productive Power of Cotton Machinery.

By D. MORRIS.

After stating that between 1760 and 1830 the inventions of Paul, Arkwright, Crompton, Hargreaves, Kay, and others, really laid the foundation of the present system of cotton factory operations, and giving a brief notice of the different machines now in use, the author described the progress made in the productive power of cotton machinery. During the last thirty years, ending in the year 1860, vast improvements had been made in the blowing-room, the machines being now entirely made of iron instead of, as formerly, part wood and part iron. The card-rooms were now almost invariably well ventilated and lighted, whilst the improvements in the carding machines were striking, the entire machines, including self-acting strippers, better clothing, and greater working surface, having undergone a total change. The drawing frame, slubbing and roving frames, had also experienced great changes for the better. Less progress had been made in the throstle frames than in any other frames in cotton machines. In the mules, both hand and self-acting, great improvements had been made in consequence principally of the many excellent appliances which had been introduced into the headstock, to save weight and bodily labour on the part of spinners. The author went at considerable length into the improvements made in looms since 1830. In the winding apparatus the only improvement was in its form, and the invention of a motion to shape the bobbin. In warping machines the latest improvement was by Messrs. Howard and Bullough, of Accrington. The tape-sizing machine, by Mr. W. Kenworthy, of Blackburn, would do the work of six of the old ball-sizing machines used in 1830. The invention of knitting-machines to knit healds was a saving of 50 per cent. in the cost of production. The folding or plaiting, or measuring machine was generally adopted, and effected a great saving of time and wages, as was also the hydraulic press. Finally, in 1764 the cotton imported into this country was 3,870,392 lbs., in 1830 239,837,350 lbs., and in 1860 1,083,600,000 lbs.; and the increase in the mills, spindles, looms, and workers was in proportion, namely:—

| | 1830. | 1860. |
|---------------|------------|------------|
| Spindles..... | 12,000,000 | 40,000,000 |
| Looms | 105,000 | 400,000 |
| Mills | 2,500 | 7,100 |
| Workers | 200,000 | 500,000 |

The quantity of raw cotton consumed in 1856 in the following countries was as follows:—Great Britain, 920,000,000 lbs.; Russia, Germany, Holland, and Belgium, 256,000,000 lbs.; France, 211,000,000 lbs.; Spain, 40,000,000 lbs.; countries bordering on the Adriatic, 39,000,000 lbs.; United States, 265,000,000 lbs.; sundries, Mediterranean, &c., 56,000,000 lbs. Total, 1795,000,000 lbs.

On Patents and Copyrights. By Professor ROGERS.

The Physical and Geographical Features of the Country ten miles round Dudley, with remarks upon the natural drainage area, as they bear upon the Sanitary Condition of the district. By HENRY C. ROPER.

On the Vital Statistics of Birmingham, and seven other Towns.

By W. L. SARGANT, of Birmingham.

This paper contained the following particulars for each of the eight towns:—1st, the population since 1801, with *absolute* increase and *rate* of increase; 2nd, the *ages* of the people at last census; 3rd, the *density*, the *birth-rates*, and the *death-rates*; 4th, the *ages* of the dying; 5th, the *excess* of death-rates over those of all England; 6th, the *causes* of death; 7th, the proportion of deaths from *each* cause to deaths from *all* causes.

A century ago Norwich exceeded each of the three towns, Liverpool, Man-

chester, Birmingham ; now these three have grown from 92,000 together to a million and a quarter.

The ages of the people show the migration that goes on. A large number of girls come into the towns as domestic servants, and a considerable proportion of these return to the country to die. The male deaths, therefore, show the sanitary condition better than the female deaths.

It is commonly believed that while the male death-rate on the whole exceeds the female, the female death-rate is the higher from puberty to middle life. The truth is, that from 1851 to 1861 the female death-rate was the higher from puberty to twenty, and about equal to the male from twenty to middle life.

Among the causes of death it is remarkable that there are no more deaths to population from cancer in unhealthy Liverpool than in all England.

From lung disease, even including phthisis, there are more male than female deaths.

Brain disease prevails little in London, much in Leeds and Sheffield.

Cholera and the cognate diseases are fatal in most of the great towns. As to typhus, London and Bristol stand well.

All these latter calculations are made for the registration districts, and not for the boroughs.

It is expected that this paper will appear at length in the 'London Statistical Journal.'

On the Admission of Illegitimate Children into Workhouses, as a means of preventing Infanticide. By E. VIVIAN, J.P.

Mr. E. Vivian, of Torquay, one of the Magistrates for the County of Devon, who committed Harris and Winsor on the charge of murdering the infant child of the former near Torquay, read a paper founded upon the following resolutions, which he intended to bring before the Board of Guardians of the Newton Abbott Union, in which the offence was committed :—

1. "That it is expedient that Boards of Guardians should be entrusted with a discretionary power to admit illegitimate and, in special cases, legitimate children, into the workhouses without their mothers also necessarily being inmates. The expense to be borne, when practicable, by one or both parents.

2. "That it should be the duty of Relieving Officers and other parochial authorities, to ascertain and place on record the parentage in all cases of illegitimate birth, and to promote the obtaining of orders of affiliation, so to prevent the burden from falling upon the ratepayers, or exclusively upon the mother, from lapse of the statutory time in making the application."

Under the present law, both these courses are prohibited. He believed that, under the surveillance of the Poor-Law Board, the discretionary power thus given to the Guardians would not be abused, and that the workhouse would afford a refuge intermediate between a Foundling Hospital, with all the encouragements resulting from secrecy, and the cruelties now practised upon the unfortunate children when put out privately to nurse. The mothers might be required to remain in the workhouse, so long as their services were required, as nurses to their own or other infants, when, at the discretion of the Guardians, they might resume their employments, and recover their lost position, which is in most cases impracticable when burdened with the care of a child.

A Statistical Review of the Police-recognised Drunkenness of the Metropolis. By R. WILKINSON.

Partly by statistics already printed by order of the House of Commons, and partly from information courteously communicated by the Chief Commissioner of the Metropolitan Police, the author was enabled to present a view of the police-recognized drunkenness of the metropolitan district, which embraces a radius of about sixteen miles from Charing Cross.

I. The apprehensions for drunkenness, and for drunkenness with disorder, during each decennial period, with the annual averages, were as follows :—

| Apprehensions. | From
1831-40. | From
1841-50. | From
1851-60. | From
1861-64. | Total from
1831-64. |
|----------------------------|------------------|------------------|------------------|------------------|------------------------|
| For drunkenness | 238,607 | 106,924 | 97,946 | 33,581 | 477,058 |
| „ drunkenness and disorder | 66,125 | 81,838 | 110,450 | 38,222 | 296,635 |
| Total | 304,732 | 188,762 | 208,396 | 71,803 | 773,693 |
| Annual average | 30,473 | 18,876 | 20,839 | 17,950 | 22,756 |

From 1831 to August 29th, 1833, it was one of the instructions of the police to take charge of *all* intoxicated persons, many of whom were dismissed by the superintendents after detention till they were sober.

The figures elucidating this point are as follows:—

| | | |
|---------------------|---------|--------|
| 1831. Apprehensions | | 31,353 |
| 1832. „ | | 32,636 |
| 1833. „ | | 29,880 |

Total for three years .. 93,869

| | | |
|------------------------------------|---------|--------|
| 1831. Dismissed by Superintendents | | 23,787 |
| 1832. „ | | 25,702 |
| To August 29th, 1833 „ | | 18,487 |

Total for three years included in the above .. 67,976

II. As to the female apprehensions of each period, it must be premised that the number of females apprehended for drunkenness with disorder, in the first decennial period, is calculated on the proportion of such cases in the apprehensions for drunkenness only.

| Cases of | From
1831-40. | From
1841-50. | From
1851-60. | From
1861-64. | From
1831-64. |
|--------------------------|------------------|------------------|------------------|------------------|------------------|
| Female drunkenness | 84,538 | 41,326 | 46,322 | 16,415 | 188,601 |
| „ „ and disorder | 23,474 | 33,048 | 46,902 | 15,118 | 118,542 |
| Total | 108,012 | 74,374 | 92,224 | 31,533 | 307,143 |
| Annual average | 10,801 | 7,437 | 9,322 | 7,883 | 9,034 |

III. In comparing the apprehensions for each period with the population of the metropolis, the estimates have regard to the probable population in the sixth year of each decennial period, 1836, 1846, 1856, and the probable population in 1862.

From these population estimates is excluded the population of the city of London, which has a constabulary of its own, and supplies statistics of its own police-recognized intemperance.

| | 1831-40. | 1841-50. | 1851-60. | 1861-64. |
|--|-----------------------|-----------------------|-----------------------|-----------------------|
| Estimated population in the Metropolitan police district | 1,700,000 | 2,200,000 | 2,500,000 | 2,950,000 |
| | To whole population:— | To whole population:— | To whole population:— | To whole population:— |
| Apprehensions per annum for drunkenness | 1 in 71 | 1 in 206 | 1 in 255 | 1 in 351 |
| Apprehensions per annum for drunkenness and disorder | 1 in 257 | 1 in 244 | 1 in 226 | 1 in 309 |
| Apprehensions for both combined | 1 in 56 | 1 in 117 | 1 in 120 | 1 in 164 |

IV. The very important question, how far these statistics indicate the extent of the actual intemperance of the metropolis, remains to be considered. In reduction of the figures presented, it is to be noted that they represent cases, not distinct persons, many of whom are apprehended more than twice in the year, and some of them many times over. If the proportion of persons to cases is placed at 2 to 3, that proportionate reduction must be made in calculating the numbers apprehended, and the proportion of those persons to the population. This rule need only be applied, by way of exemplification, to the annual average for the last four years, and it will give—

| | | | |
|--|--------|--------------------------------|-----|
| Persons apprehended for drunkenness | 5,597 | .. Proportion to population .. | 527 |
| Persons apprehended for drunkenness and disorder | 6,370 | .. Proportion to population .. | 463 |
| Persons apprehended for both causes | 11,967 | .. Proportion to population .. | 247 |

If we turn to the facts, which evince a prevalence of metropolitan intemperance far exceeding the proportions represented by the statistical data, we shall find them to consist of the following:—

1st. The fact that police apprehensions are limited to cases of aggravated intemperance coming under the view of the police. In 1834, when Col. Rowan, one of the Police Commissioners, was under examination before Mr. Buckingham's select committee of the House of Commons, he stated that, as to cases of intoxication unconnected with disorder, he believed that only one in three came into the custody of the police. The night-police are specially disposed to do as little as they possibly can in the apprehension of drunkards, as they have to lose their next day's rest, to give witness against the accused persons. The police pretend to arrest drunk and incapable, and drunk and disorderly persons only, but (1) many of even such cases they never see, and (2) not a few of those seen are let alone from the trouble they would entail, or the wish to preserve individuals, otherwise respectable, from exposure.

2nd. There is the fact that all persons intoxicated, who can manage to get along with or without the help of others, are systematically avoided by the police.

3rd. There is the fact that, as compared with the population, the very young and the aged are necessarily excluded from the calculation. This is at once equal to raising the proportion of arrested persons to the population almost one half; so that instead of 1 in 247, we might read 1 in 125.

4th. There is the fact that the intemperance practised in private is in a great degree withdrawn from the cognizance of the police.

All these considerations tend to prove that the actual arrests for aggravated intemperance by no means represent the total of such public cases; that they absolutely exclude all private cases of that kind; that they are independent of all cases of simple intoxication, as such; and that they have nothing to do with that habit of tippling, the cause of much disease, poverty, and crime, but not necessarily taking the developed form of positive intoxication.

There are about 10,000 drinking shops in London, and it would be a very moderate estimate that would assign to each on every Saturday night twenty persons in different stages of intoxication; and supposing that these were the same persons every Saturday night (though often they are not the same), they would exhibit a total of 200,000 individuals, mostly of middle age, living in the metropolis alone, who periodically subject themselves to the vice of intoxication, a number equal to 13 per cent. of the adult population, or 1 in every 8 persons. How this result can be materially altered while the licensed temptations to drinking remain as they are, the moralist and statesman may well despair of discovering. Public-house associations are perpetually extending, and the evils are transmitted from one generation to another.

Some vigorous effort for the reduction of drinking shops is the only resource left, since purely moral and reformatory agencies are counteracted more successfully than they counteract the opposite influences.

No remedy yet proposed will be effectual unless it includes a suggestion thrown

out by Mr. Charles Buxton in 1855, and adopted by the United Kingdom Alliance in 1857, by which every parish and township would be empowered to settle for itself whether drinking shops should continue to be licensed or not within its limits. Where the public sentiment was averse to the common sale of intoxicating liquors, all houses for public refreshment would be carried on without such sale; and the author believed that an immediate and most gratifying change would soon ensue in regard to the drunkenness and crime by which these places may have been afflicted.

On Mural Standards for exhibiting the Measures of Length legalized in the United Kingdom. By JAMES YATES, M.A., F.R.S.

The only mural standards exhibited in this country known to the author are those in the National Gallery, Trafalgar Square, London, where are seen the metre, the yard, the braccio, and the palm; secondly, those on the outside wall of the Royal Observatory at Greenwich, showing the yard, the foot, and the inch; and thirdly, three similar instruments put up and exposed to public view by the Messrs. De la Rue in Bunhill Row, London. Nevertheless the exhibition of similar standards is required by law and practised in France, and its adoption in this country has been recommended by the Royal Commission for restoring the lost standards*. The present period seems eminently suitable for the more perfect attainment of this object, because the English system of legal weights and measures has received an enlargement of the highest importance by the passing of the Act for legalizing the metric system. Also the existing standards in many of the cities and boroughs of the United Kingdom are extremely faulty.

The only measures which can be conveniently exhibited on the walls of public buildings, are the measures of length. These are the yard and the metre, with their divisions. My design in this paper is to inquire how these can be exhibited by means of mural standards in the best manner. The inquiry may be conducted under the following heads: the material; the form and dimensions; the description by means of letters, figures, and other marks; the distribution and exposure to public view; the use in education; the aid to be afforded by the British Association.

I. *The Material.*—The material which I am disposed to recommend is that variety of gun-metal which is known by the name of Baily's metal, having been introduced into use for similar purposes by the late Francis Baily. The standard yard of Great Britain is made of this metal, as prescribed by the Act of Parliament, 18 & 19 Victoria, c. 72. It is a mixture of copper, zinc, and tin, as follows:—

| | |
|--------------|-----------------|
| Copper | 16 |
| Zinc | 1 |
| Tin | 2 $\frac{1}{2}$ |

The great recommendation of this metal is that it does not rust. In other respects it is probably on a par with the other metals which are used or may be suggested for similar purposes, such as gold, silver, platinum, copper, brass, bronze, steel, or

* "Another measure ought, in our opinion, to be effected by the authority of the Government; namely, the fixing of mural standards of length in public places, where they may be accessible to the people generally. This is done under the Prussian law; and we are supported by the evidence of practical men, that it would conduce most powerfully to the dissemination of good measures of length."—Report of the Commissioners for Restoration of the Standards, A.D. 1841, p. 16. This recommendation was seconded in the following terms by the Select Committee of the House of Commons on Weights and Measures, A.D. 1862. "Public standards should be exhibited (as barometers are at our ports and fishing-stations) in conspicuous places in our towns, and secured (as they are on the Continent) by insertion in the walls. 'There is no such thing in Britain,' says the Astronomer Royal, 'as a public exhibition of a measure or a weight.' The Government, instead of being passive, ought to be active in the question."—Report, p. ix. The Astronomer Royal's letter, here quoted, is dated 1st February, 1859. It is addressed to Lord Monteagle, at that time Comptroller of the Exchequer, and is highly deserving of attention.—See Appendix to same Report, p. 225.

aluminium bronze. It is sufficiently hard; it is fusible, and takes good impressions in the mould; it shows fine and clear lines on being engraved*.

II. *Form and Dimensions.*—I propose that the instrument should be 102 centimetres long, 6 centimetres broad, and 1 centimetre thick. The reasons for adopting these dimensions will be explained in the sequel.

III. *Description by means of Letters, Figures, and other marks.*—For the composition and arrangement of these I am indebted to Mr. Frank Fellows.

The yard is placed above, the metre below. Above the yard is its description, in these words: "Yard divided into Feet and Inches," after which the title of the Act of Parliament is quoted, by which Act the yard is defined, and its legality established, viz., "5 Geo. IV. ch. 74." The space on which these titles are to be inscribed is proposed to be 1 centimetre broad.

The antithesis to this space is that at the bottom of the instrument, also 1 centimetre broad. It describes the measure immediately above it, and the Act of Parliament by which that measure is defined, and its legality established: "Metre divided into Decimetres, Centimetres, and Millimetres.—27th and 28th Victoria, ch. 117."

The middle breadth of 4 centimetres is equally divided between the yard and the metre. Each of these has a space of 2 centimetres broad, and the space belonging to each is again divided into equal breadths, each of which has consequently a breadth of 1 centimetre. The space belonging to the yard is a yard long, and is intended to be the exact measure of a yard. The space beneath it, and contiguous to it, belonging to the metre, is, in like manner, intended to be the exact measure of a metre.

The upper half of the space belonging to the yard, being a centimetre broad, is divided lengthways into 3 feet; the lower space, also a centimetre broad, is divided into 36 inches. Thus far the division is that appointed by Act of Parliament. But we have thought a further subdivision expedient, through a small portion of the scale, viz., the division into eighths of an inch. We have chosen eighths rather than tenths or twelfths of an inch, because eighths are far more extensively in use, and also some persons of eminence and high authority in this country think a binary much preferable to a decimal or duodecimal division.

Proceeding on the same principle and in strict conformity with the law of the country, we divide the metre lengthways into decimetres, centimetres, and millimetres. But whereas the yard has the greater divisions placed above and the smaller divisions below, we have in the case of the metre placed the smaller divisions above and the larger below. This arrangement produces great facilities for comparison, because it brings the small divisions of the two scales into immediate apposition. Thus we find as approximations,—

| | | |
|-------------------------|-----|--------------|
| One eighth of an inch = | 3 | millimetres. |
| One quarter „ = | 6 | millimetres. |
| One half „ = | 12½ | millimetres. |
| One inch = | 25 | millimetres. |
| Two inches = | 50 | millimetres. |
| Four inches = | 100 | millimetres. |

For greater exactness reference may be made to Rickard's Ready Reckoner, or Dowling's Comparative Tables.

It is necessary to observe that both of these scales begin from the left hand, and from the same perpendicular line.

The spaces at the two ends of the instrument, which are extraneous to the yard and metre scales, are each half a centimetre wide. They will serve as guards to the two scales. The name of the maker of the instrument may be engraved on the right hand. If the manufacture of these standards is entrusted to well-qualified persons, if they are provided with exact standards for their own use, and if they bestow due pains and care on those which they produce, the standards of their making will be sufficiently accurate for all common practical purposes, and there will be no necessity to seek assistance in providing lineal

* Notwithstanding these real or supposed advantages, the use of Baily's metal has been abandoned in favour of the adoption of glazed or enamelled porcelain.

measures from the Government. But the name of an artist of established reputation ought to be shown on the mural standard as a voucher for its correctness.

IV. *Distribution and Exposure to public view.*—This part of the subject will be more especially considered when we come to the last division, viz., the assistance to be afforded by the British Association. At present I will only make the obvious remark, that the mural standards should be put up wherever they will be least exposed to injury, and can be seen, examined, and compared by the greatest number of persons.

V. *Use in Education.*—The immediate and primary use of these standards will be to make the two methods of linear measurement universally known, to render the terms, especially those belonging to the metre, familiar to the people, and to enable all persons to verify their own measures. But it is important to have an eye also to the use of these instruments in education. For this purpose I have proposed exact dimensions in length, breadth, and thickness, on the metric scale. The consequence will be that they may give many useful and interesting lessons in mensuration and geometry. In this way the instrument may be of great use in large schools for every class of the community. It will be observed that the space, one centimetre wide, which is immediately below the yard, is divided into 100 square centimetres. The dimensions of the other spaces being borne in mind, the following questions and answers will illustrate the present subject.

What is the area of this mural standard in square centimetres?—*Answer*: $101 \times 6 = 606$ square centimetres.

State also what is the area in square decimetres and millimetres.

Answer: 6.06 square decimetres.

60600 square millimetres.

What proportion does this surface bear to that of a square metre or centiare?—

Answer: as 606 to 10,000 $= \frac{606}{10,000} = \frac{151.5}{2500}$.

Give the solid contents of the instrument in centimetres, supposing it to be one centimetre thick.—*Answer*: 606 solid centimetres.

What part is this of a solid metre?—*Answer*: $\frac{151.5}{250,000}$.

What is the weight of the instrument, supposing the specific gravity to be 2.6?—*Answer*: $606 \times 2.6 = 1575.6$ grams., or 1.5756 kilos.

VI.—*Aid to be afforded by the British Association.*—Since the promotion of the metric system is an object of universal interest, and one in which science has been applied in the most admirable manner to practical purposes, there is none to which the British Association for the Advancement of Science can with greater propriety extend its patronage, and devote a portion of its funds. In connexion with this object a Committee was appointed at Newcastle-on-Tyne; this Committee was reappointed last year at Bath, and was authorized to spend the sum of £20. This money has not been applied for, no specific object requiring such an expenditure having presented itself to the Committee. Let the Committee be reappointed. Let it be encouraged to proceed, and authorized to construct mural standards of the best possible description. Let one of these be offered to every place where the British Association has held a Meeting, two or three being offered where two or three Meetings have been held. Let the authorities of these towns, cities, or universities be requested to expose these standards to view in such places and in such manner as they may judge most suitable and expedient. The Association may thus acknowledge, in a handsome and appropriate manner, the kindness and generosity which it has experienced; it may confer a public benefit, and supply a great deficiency in the provisions for conducting trade; it may aid the movement, than which none, perhaps, is at the present moment more important in the interests of education and philanthropy, and it may vindicate and exalt science in the eyes of all reflecting persons, by showing its utility in every-day life, and in all commercial transactions.

Statistical Data in Relation to the Representation of the People. By LEONE LEVI, Doctor of Economic Science of the University of Tubingen, Professor of the Principles of Commerce and Commercial Law in King's College, London, F.S.A., F.S.S., &c.

Great as were the difficulties of applying the theoretic principles of political science to public administration, harder still was the task imposed on the legislator when he touched the question of parliamentary franchise, a subject so intimately connected with constitutional rights and political conflicts. Without entering into the troubled waters of party politics, the author proposed only to give some statistical data as might serve to mature any views on a matter most important to the well-being of the people, remembering that political science is founded on inductive reasoning and on facts drawn from political arithmetic. Upon a review of the electoral laws of different countries, the author stated, that in France universal suffrage was established in 1852; in Germany the qualifications were birth or naturalization in the country, age, which in Prussia and Austria is fixed at 24 years, independence, and the payment of a certain amount of taxes. In Spain the limit of age is 25, and the tax which a person need pay to have the right to vote is 400 reals, with exemptions for members of scientific bodies or professional men. In Belgium, also, the age of the voter must be 25, and he must pay a tax of 42 frs. 32 cents. In Italy the age fixed is 25, the tax is 40 frs., and the elector must be able to read and write, except in certain provinces especially designated, but there are many exemptions to the condition of taxation in favour of members of academies, &c. In the United States of America the law differs in each State*. The age is generally 21. The payment of any tax assessed within two years is a condition in Massachusetts, as well as reading and writing. In Rhode Island the voter must own real estate worth \$134, or rent \$7 per annum; or must pay \$1 tax, or have done militia service within the year. In Connecticut the voter must be able to read and write. In Pennsylvania the voter must have paid a tax within two years. The same is in Delaware. In North Carolina the voter must possess a freehold of fifty acres for six months. In Georgia he must have paid all taxes required of him. The time of residence in the State before any one can vote differs also materially, and distinction is made of colour. Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Wisconsin make no legal distinctions on the ground of colour. In New York coloured citizens must be owners of a freehold worth \$250. The other States deny the right of suffrage to the Negro. In the United Kingdom a difference is made between county and borough electors, the rent of the house or tenement occupied being taken as a basis for the right,—in the county the limits being £50; in the borough, £10. The population of England and Wales on the 6th of April, 1861, was 20,066,224, of whom 9,776,259 were males, and 10,289,965 females. Taking for granted that women are not entitled to the franchise, politics not being their vocation, we have to eliminate first all the female population, and afterwards from the males those under 21, and it appears that the number living of 21 years and upwards in 1861, was 5,181,548. From this number we must deduct 12,000 deaf and dumb, 24,000 in asylums, and 10,000 in hospitals. The blind, 20,000 in number, need not be excluded, but we may take one per cent. of persons ill and bed-ridden, or 50,000. Making these deductions from the number of males of age, the number physically able is reduced to 5,045,000. But to be able to vote, a certain amount of intelligence seems requisite, and the least requirement would appear to be ability to read and write. We have no absolute test to ascertain who cannot read and write, but the number of persons who sign their marriage register with a cross is a sufficient guide. Now it appears that, in 1861, of 100 men married, only 75 wrote their names, one-fourth of the whole signing their register with marks. If we take this as a guide, about 1,250,000 should be deducted for intellectual disqualification. And then there are the paupers, criminals, army and navy, officers of the revenue, servants, &c. &c., comprising large numbers incapacitated from moral, social, or official causes. Taking all together we might

* See Bacon's Descriptive Handbook of America. By George Washington Bacon and William George Larkies.

not be far wrong in assuming that in 1861 there were not more than about 3,500,000 absolutely in a position to exercise their constitutional right in an intelligent and independent manner, even if some sort of universal suffrage were established. And if that were the case, should all have equal votes? Should the rich and the poor, the largest and smallest contributor to the public revenue stand in an equal position? We have no mode of arriving at the wealth of the different classes. As to taxes, it is true, that all pay more or less something, yet the proportion is very different. Assuming the population of the United Kingdom at 29,000,000, the proportion may be taken to be 1,000,000 upper classes, 9,000,000 middle, 18,000,000 lower, and 1,000,000 paupers; and taking the average amount of revenue and local taxation at £70,000,000, the taxes paid constituted a burden of £22 per head on the upper, of £3 9s. on the middle, and of £1 1s. per head on the lower. In fact 70 per cent. of the revenue was obtained from about 30 per cent. of the population. There would be great difficulties in arriving at anything like a correct and equitable apportionment of votes in relation to wealth and payment of taxes, especially as we have no direct public tax sufficiently low to include the entire community, and it may be taken for granted that any attempt in that direction would be sure to fail for want of data. Abandoning therefore any hope to arrive at an equitable adjustment by any such conclusion, we come to the present test of the house rent. The intention of this plan seems to be the bringing in within the pale of the constitution all those who live in sufficient comfort and affluence as an indication of a sound civil condition. Taking this test, we have the fact that at the time of the census there were 3,739,505 inhabited houses, producing an estimated rental of £58,013,181, which gave an average of £15 5s. per house. But of this number, 3,219,514, or as many as 86 per cent., were rented under £20; and of these, 459,693 houses only were rented at from £15 to £20; 822,149 were rented at £10 to £15; 1,277,956 were rented at from £5 to £10; and 659,724 houses were rented at from £3 to £5. The largest number of persons live in very low rented houses, which indicate great discomfort if not wretchedness; and this is especially the case in large towns, where house rent has much increased, as well as in the agricultural and mining districts. Hence it is that by this test the largest number are practically disqualified. In fact the number of persons having votes is now less than one million against 5,000,000 males of age, or 3,500,000 of persons free from any personal disqualifications. From several returns relating to the economic condition of the people, it appears that the consumption of articles of food and comfort has largely increased of late years, that the amount deposited with savings banks is much larger, and that the number of children at school is considerably larger, facts which seem to indicate a large increase of comforts and welfare among all classes. Yet it is evident that there are large masses of the people possessing very scanty means and who are very deficient in intellectual acquirements, and that if the franchise was lowered to rents from £5 to £10 the number of voters added would be considerable, including probably not a few of the lowest class of society. Should such an extension be attempted, a restriction should certainly be imposed as regards persons unable even to read and write. If we can go no further in the way of imposing an educational test, let it be provided that henceforth at least the franchise shall be given to those only who can sign their own names in the register, an alteration being made for the purpose in the method of recording the vote at the poll. It should be our aim to hold out the right to vote as a premium to self-mastery and frugality; and if the State cannot undertake to educate and elevate the masses of the people, let it at least show that for the exercise of the higher functions of a free man in a free state, the citizen must prepare himself by a life unstained in character, high in moral principle, and well-trained and enlightened in the great school of constitutional and political government.

MECHANICAL SCIENCE.

Address by Sir W. ARMSTRONG, K.C.B., F.R.S., President of the Section.

GENTLEMEN,—The Mechanical Section of the British Association is fortunate this year in having the Annual Meeting held at Birmingham. In no other town in the kingdom are mechanical and manufacturing processes carried on in greater variety, and the Members of this Section cannot fail to derive both pleasure and profit from the opportunity thus afforded them of witnessing these manifold branches of industry, and of discussing amongst themselves the various objects brought before them. Let it also be recollected that we are here on ground rendered classic by the labours of Watt. It was here that he reduced to practice those splendid mechanical conceptions which have contributed more than anything else to the marvellous progress of the last half century. Every relic of the great mechanician which may here be presented, will excite reverential feelings in our minds, and we shall be especially interested in the collection of his original models, which I understand are to be submitted to our inspection at the *conversazione* this evening in the Town Hall.

The papers to be read to the Section embrace, as might be expected, matters of great interest and importance, and will, I trust, give rise to much instructive discussion. Nothing can be more surprising than the recent rapid and still accelerating progress of mechanical science, and assuredly this progress is in no small measure attributable to the facilities afforded by such occasions as the present for a more easy and general interchange of experience and ideas. Amongst the papers to be read I notice one by Mr. Robinson, of Manchester, on the subject of that interesting and most curious apparatus, "Gifford's Injector;" and I anticipate that Mr. Robinson's experience will enable him to throw additional light upon this paradoxical machine. Should any obscurity remain, it will, I hope, be cleared up by the observations which this paper will call forth.

The subject of hewing coal by machinery will be brought before the Section by Mr. Levick. I refer to this subject with much satisfaction, not only on account of its importance, but also as being a successful step in mechanical science accomplished during the year which has elapsed since the last Meeting of the British Association. It may be a matter of regret with some persons that the application of machinery to this and other similar purposes will operate to deprive labourers of their employment; but it must be admitted that whatever tends to economise human labour in the dark and dangerous recesses of a coal mine, must be a benefit to the community; moreover, all experience has shown that although labour may be diverted in its channels by the introduction of machinery, the aggregate amount of employment suffers no diminution, but, on the contrary, seems to increase.

I regret that we are not also to have a paper on the progress which has been made in puddling by machinery, and I trust that when another year has passed away, the President of this Section will have occasion to notice the attainment of complete success in that desirable object.

The paper from Mr. Bessemer upon steel cannot fail to be highly valued by the Section. The growing importance of this material, and its rapidly extending sphere of usefulness, have attracted attention in a special degree to the question of economy in its production; and certainly no one has contributed so largely as Mr. Bessemer to our advance in this direction.

The various papers which are to be read on deep-sea telegraphic cables will prove peculiarly acceptable at the present moment, when our interest is so much engaged in the grand attempt to establish telegraphic communication between England and America. Never was there an undertaking which presented such formidable risks and difficulties at the outset; never were more discouraging failures experienced, and never were failures encountered with more indomitable courage and perseverance. Such enterprise as this reflects credit, not only upon the individual promoters of the undertaking, but also upon the nation itself.

The paper promised by Mr. Cox upon Mr. Siemens's regenerative furnace will bring forward a subject the importance of which can in my opinion scarcely be over estimated. Few people are aware of the prodigious waste of heat which takes place in all furnaces where it is requisite to communicate a high temperature to

any material. If, for example, a mass of material is to be heated to a temperature of 2000° by flame of a temperature of 3000° , it is plain that the heating gases must, in the ordinary furnaces, escape at a temperature equal to that of the material, and thus carry off with them a heat which will, when the maximum temperature is attained, amount to two-thirds of the whole heat and combustion. The regenerative furnace arrests a large proportion of this fugitive heat, and adds it to the gaseous fuel which supports the combustion of the furnace. Wastefulness must always be deprecated in mechanical processes; but considering how much the greatness of this country is dependent upon her resources of mineral fuel, and with what prodigality we are now drawing upon these resources, any wholesale wastefulness demands especial reprobation, and renders the introduction of more economical methods of consumption a matter of national importance. The regenerative gas-furnace not only prevents waste of fuel, but it also prevents smoke. Smoke may be altogether prevented, and is in fact inexcusable in the case of ordinary steam-boiler furnaces; but I know of no means yet introduced by which its prevention can be effected in manufacturing furnaces heated directly by coal. If gas were substituted for coal, and the regenerative principle applied, the nuisance and disfigurement occasioned by smoke would be entirely avoided in nearly all manufacturing processes. But the introduction of gas-furnaces upon so large a scale must necessarily be a work of considerable time, and the system itself would probably require improvement and development to render it so widely available.

I might extend my observations to the subjects of other papers to be read before you, all of which possess considerable interest; but I feel that little would be gained by such an extension of my comments, and that it is better for us at once to proceed to the proper business of the Section.

On Chain-testing Machines. By Sir W. G. ARMSTRONG, F.R.S.

The machines referred to were constructed for the Mersey Harbour Trustees. The most important consideration in the construction of a chain-testing machine was to obtain an accurate indication of the strain upon the chain. The hydraulic press had been the means employed of exerting the strain, but the method for determining the amount of strain had been extremely imperfect. Most commonly, the strain had been estimated by the indications on a mitred valve pressed down by a lever and weight. This mode of indication he considered was highly delusive, and he pointed out the advantages of substituting a packed loaded plunger for the loaded valve. The packing should consist of cup leather, so that the friction should vary directly as the pressure. When a chain broke in the test, it was desirable to show not only that it failed to bear the full test strain, but also the amount of strain exerted at the moment of fracture. The pendulum indicator has now been brought into general use. In this the pressure upon the plunger is exhibited by the motion of a pendulum through a graduated arc. When a chain broke, the pendulum fell back until stopped by a ratchet, but left a marker at the exact point on the scale attained by the pendulum. Having spoken of the effect of friction on the results indicated, the author proceeded to say that in the arrangement of a public chain-testing establishment it was desirable that the apparatus for the various operations should be placed in such succession as would allow the chains to move from process to process without any retrogression. The Birkenhead establishment was then described, in which the machines are adapted to cable lengths of fifteen fathoms, the Board of Trade having recently fixed upon that length as the limit of chain to be tested at one time. He thought the restriction very desirable, and referred to many objections to testing chains in greater lengths.

On the Manufacture of Cast Steel, its Progress, and Employment as a Substitute for Wrought Iron. By HENRY BESSEMER.

On the 13th of August, 1856, the author had the honour of reading a paper before the Mechanical Section of the British Association at Cheltenham. This paper, entitled "The Manufacture of Malleable Iron and Steel without Fuel," was the first account that appeared shadowing forth the important manufacture now generally known as the Bessemer process.

It was only through the earnest solicitation of Mr. George Rennie, the then President of the Mechanical Section of this Association, that the invention was, at that early stage of its development, thus prominently brought forward; and when the author reflects on the amount of labour and expenditure of time and money that were found to be still necessary before any commercial results from the working of the process were obtained, he has no doubt whatever but that, if the paper at Cheltenham had not then been read, the important system of manufacture to which it gave rise would to this hour have been wholly unknown.

A diagram showed in section the original fixed converting vessel, as patented and erected in London for experimental purposes in 1856. It was observed that the tuyeres were passed through the sides of the vessel in a horizontal direction, the result was that the blast of air entered only a short distance into the fluid mass, and much of it escaped upwards between the sides of the vessel and the metal. The effect of this was the rapid destruction of the brick lining, caused by the excessive temperature generated in the process and the solvent property of the resulting silicate of protoxide of iron, which sometimes destroyed a lining of half a brick in thickness during the blowing of two charges of metal for about twenty minutes each. Another difficulty arose from the impossibility of stopping the process without running out the metal; for if the blowing ceased for one instant, the fluid metal would run into the tuyeres and stop them up.

A great inconvenience of the fixed vessel also arose from the danger and difficulty in tapping out the fluid malleable iron with a bar, after the manner of tapping an ordinary cupola furnace, for the blast had to be continued during the whole time the charge was running out of the vessel in order to prevent the remaining portions from entering the tuyeres. A similar difficulty arose while running in the crude metal from the melting furnace, since it was necessary to turn on the blast before any metal was run into the vessel; the first portions so run in were in consequence partially decarbonized before the whole of the crude metal had left the melting-furnace.

These were among the more prominent difficulties that had to be remedied. It is, however, satisfactory to know that even in this, its infant state, the process and apparatus were practically successful, in proof of which there is placed upon the table part of a malleable iron railway bar made from pig iron, at Baxter House, by blowing air through it in the apparatus just described, the fluid malleable iron having been run into a 10-inch square ingot mould and the bloom so made rolled direct into the bar shown. The small malleable iron-forged gun will serve as an example of the clearness and freedom from cracks or flaws in malleable iron so made and forged under the steam-hammer. It is one of the very early productions of the process, and, like the malleable iron rail, was made wholly without any recarbonizing of the metal, or the employment of spiegeleisen or manganese in any form whatever. Malleable iron so made from hematite pig iron is red-short, like all other wrought iron made wholly from hematite; but that it is perfectly malleable and extremely tough when cold, may be seen on examination of the iron rope exhibited, which consists of four rods of $1\frac{1}{2}$ -inch round iron twisted cold into a close coil. These bars extended 13 inches in length in 4 feet, and were reduced nearly $\frac{1}{8}$ inch in diameter in the operation of twisting, thus showing that malleable iron so made possesses an extraordinary degree of ductility.

It may be remembered that an important part of the process, as described at Cheltenham in 1856, consisted in tapping the fluid crude iron from the blast-furnace, and allowing it to flow directly into the converting-vessel, and be there blown to the extent only of decarbonizing it so far as to produce cast steel. This part of the original programme has been most successfully carried out in Sweden, where an extensive establishment for its manufacture has been erected by M. Göransson, of Gefle. The large steel circular saw plate exhibited is an example of the conversion of crude cast iron run direct from the blast-furnace into the converting-vessel, and there blown for nine minutes, in which period it had been converted into cast steel of the desired quality, and was then poured into an ingot mould without being recarbonized, and wholly without the employment of spiegeleisen or manganese in any form whatever.

With these few illustrations of the capabilities of the process as originally de-

scribed at Cheltenham, the author proceeded to show how the disadvantages of the old fixed converting-vessel were remedied and other improvements introduced. Many forms of converting-vessels were tried on the large scale before this desirable object was attained. In some of them the lining was too easily broken down by the violent motion of so heavy a fluid as iron; in some of the forms tried the angles allowed the metal to solidify in them, and so clog up the vessel; in others, the mouth of the vessel being too small, caused the metal to be thrown out by the force of the escaping blast. It was also found that if the mouth was too large the heat escaped, so as to cause part of the converted metal to solidify in the vessel; the relative height and diameter of the vessel was also found to produce important differences in the working of the process; finally, and after many long and expensive trials, the form of vessel shown in a diagram was adopted. This vessel is made in two parts, so as to admit easily of its being lined up with a pulverized siliceous stone, known as 'ganister,' which so resists the action of the heat and slags as to last for fully 100 consecutive charges of steel before it is worn out. Its form is that of the arch in every position which prevents the lining from falling down by its own weight. There are no angles in which the splashes of metal can solidify and accumulate. Its mouth directs the flame and sparks away from the workman, and from the moulds and other apparatus; while the throat of the vessel, and the position of the mouth, almost entirely prevent the throwing out of the metal. The vessel is mounted on trunnions supported on stout pedestals, so that a semirrotary motion may be communicated to it at pleasure. The tuyeres are placed at the bottom of the vessels, so as to force the air vertically upward through the metal, as shown, without coming in contact with the sides of the vessel. When the crude metal is to be run into the vessel, it is turned on its axis nearly into the position shown, the mouth being a little higher up; a gutter will then conduct the crude cast iron from the melting-furnace into it. It is not necessary to turn on the blast until the whole of the metal is run in, because the tuyeres occupy a position above the level of it. As soon as the air is admitted through the tuyeres, the vessel is turned into the position shown, when its decarbonization immediately commences. As soon as this is effected, as much molten pig iron made from spathose iron ore is added to it as will restore the quantity of carbon necessary to produce the desired quality of steel, which is then run into the casting ladle in the manner shown, and from whence it is transferred to a series of iron moulds ranged in a semicircular pit, each mould being placed within the sweep of the casting-crane; the filling of these moulds is regulated by a cone valve made of fireclay and fitted in the bottom of the casting-ladle, so as to be opened or shut at pleasure by means of a handle on the outside of the ladle.

It will be readily understood that in the fixed vessel first described any giving way of a fireclay tuyere would stop the process and cause much inconvenience; but with the moveable vessel it is not so, for at any moment of time during the process the vessel may be turned on its axis and the tuyeres raised above the level of the metal; the blast may then be turned off, the tuyere box opened, and the faulty tuyere stopped up or removed, after which the process may be again resumed. The movement of the vessel on its axis, the rise and fall of the casting-crane, and the other cranes employed for removing ingots from the casting-pit, are all effected by a simple hydraulic apparatus, so that the whole process is under the perfect control of a single operator, placed far away from the heat and showers of splashes that accompany the process.

Up to this period the manufacture of cast steel by the old as well as the new process is still so far imperfect that steel of the highest quality cannot be made from inferior iron. In the old Sheffield process the original quality of the Swedish charcoal iron employed governs the quality of the cast steel made; consequently £36 per ton is freely given for the high class Danamora iron, while other brands of Swedish charcoal iron may be bought for £15. In either case these are expensive raw materials for the cast-steel maker.

In 1839 the trade of Sheffield received an enormous impulse from the invention of Josiah Marshall Heath, who patented in this country the employment of metallic manganese, or, as he called it, 'carburet of manganese.' The addition of a small

quantity of this metal, say from one-half to one per cent., rendered the inferior coke-made irons of this country available for making cast steel; it removed from these inferior qualities of iron their red-shortness, and conferred on the cast steel so made the property of welding and working soundly under the hammer. This invention was of immense importance to the town of Sheffield, where its value was at once appreciated. Mr. Heath, supposing himself secure in his patent, told his licensees that if they put oxide of manganese and coal tar or other carbonaceous matter into their crucibles along with the blister steel, it would do as well, and be much cheaper than the carburet of manganese he was selling them; in effect it was the same thing, for before the steel was melted the carbon present reduced the oxide of manganese to the metallic state, so that his patent carburet of manganese was formed in the crucible in readiness to unite with the steel as soon as it became perfectly fused. But the law decided that this was not Heath's patent, and so the good people of Sheffield, after many years of litigation, were allowed to use it without remuneration to the inventor.

Manganese has now been used for many years in every cast-steel works in Europe. It matters not how cast steel is made, since manganese added to it necessarily produces the same beneficial changes; no one better appreciated this fact than the unfortunate Mr. Heath, as evidenced by his patent of 1839, in which he declares that his invention consists in 'the use of carburet of manganese in any process whereby iron is converted into cast steel.' Had Heath seen in his own day the Bessemer process in operation, he could not have said more; he well knew the effect produced by manganese on steel, and therefore claimed its employment in any process whereby iron is converted into cast steel.

With this patent of Heath's expired and become public property, coupled with the universal addition of manganese and carbon to cast steel, it would naturally be supposed that the author, in common with the rest of mankind, would have been allowed to share the benefits which Heath's invention had conferred on the whole community; but it was not so.

The reading of the author's paper at Cheltenham in 1856 was, by the powerful agency of the press, communicated in a few days to the whole country. Great expectations of the value of the new process were formed, both by scientific and practical men, in proof of which it may be stated that licenses to manufacture malleable iron under the patent were purchased by ironmasters to the extent of £25,000 in less than twenty-five days from the reading of the Cheltenham paper. Great excitement existed at that moment in the iron trade, and many persons seemed to covet a share in an invention that promised so much; there was consequently a general rush to the patent office, each one intent on securing his supposed improvement. It was thought scarcely possible that the original inventor should at the very outset have secured in his patents all that was necessary to the success of so entirely novel a system, he must surely have overlooked or forgotten something; perhaps even left out all mention of some ordinary appliance too well understood to need really mentioning; so in the jostle and hurry to secure something, any point on which a future claim could be reared was at once patented. Some of these gentlemen even repatented portions of the writer's own patents, while others patented things in daily use, in the hope that they might be considered new when added to the products of the new process.

Within six weeks of the date of the Cheltenham paper, Mr. Robert Mushet had taken out three patents, which form part of that long series of patents by which he hoped to secure to himself the sole right to employ manganese in combination with iron or steel made from pig iron by forcing atmospheric air through it. In this long series of patents almost every conceivable mode of introducing manganese into the metal is sought to be secured. It was claimed if used in combination with pitch, or other carbonaceous matter; it was claimed if simply used in the metallic form, or as Mr. Heath calls it, a carburet of manganese; it was also claimed if combined with iron and carbon—as in spiegeleisen. Manganese, in any of these states of combination, was claimed if put in with the metal prior to the commencement of the process; it was claimed if put in during the continuation of the process, and claimed if added to the steel after the process had been completed; it was

also claimed if put into any furnace, crucible, or vessel that the converted metal might be run or poured into; in fact manganese and its compounds were so claimed under all imaginable conditions that if this series of patents could have been sustained in law it would have been utterly impossible for the author to have employed manganese with steel made by his process, although it was considered by the trade to be impossible to make steel from coke-made iron without it.

In the 'Mining Journal' of September 24th, 1853, just four years before the first of Mr. Mushet's series of patents, a letter was published on the subject of Heath's invention. The writer of that letter says, "I am a steel maker, and deny that steel was ever made with the addition of carbon and manganese or carburet of manganese previously to Heath's invention, and I confidently assert that no cast-steel maker can now carry on his business to profit without the aid of carburet of manganese. There are," he says, "a hundred methods of improving steel with manganese, but they all involve the same principle. Put carbon and manganese into the steel pot in any form you please and at any time you like, and if the steel be thoroughly melted, the carburet of manganese melts also and is alloyed, and the improvement is unerringly effected, and by the use in every instance of carburet of manganese."

This letter clearly shows how well the subject was understood in the steel trade thirteen years ago.

Very soon after the reading of the Cheltenham paper several rough trials of the Bessemer process were made privately by persons in the iron trade, and defects discovered which were supposed by practical men to be perfectly fatal to the invention. Once more the press teemed with accounts of the process, but this time it spoke only of its utter impracticability, and of regrets that the high expectations originally formed were so fallacious. The storm, however, gradually subsided, and the process and its author were soon entirely forgotten. Imperfections in the process there certainly were, but the author had had the most irrefragable proofs of the correctness of the theory on which his invention was based, and also that the reasoning on which it was so utterly condemned by the trade was in itself wholly fallacious; he therefore decided not to argue the question against a hundred pens, but to energetically prosecute his experiments and to remain silent until he could bring the process to a commercial success. When, at the expiration of about three years of incessant labour on the part of himself and his partner, Mr. Longsdon, and an expenditure of more than £10,000, the process was again brought before the public, not the slightest interest was manifested by the trade: it had been for years agreed on all sides that it was a total failure, and was looked upon simply as a brilliant meteor that had suddenly flitted across the scientific horizon, leaving the subject in more palpable darkness than before. This entire want of confidence on the part of the trade was most discouraging; one of two things became imperative, either the invention must be abandoned, or the writer must become a steel manufacturer; the latter alternative was unhesitatingly accepted, and Messrs. Henry Bessemer and Co. determined to erect a steel works at Sheffield, in the very heart of that stronghold of steel making. At these works the process has ever since been successfully carried on; it has become a school where dozens of practical steel makers received their first lessons in the new art, and is the germ from which the process has spread into every state in Europe, as well as to India and America.

By the time the new works at Sheffield had got into practical operation, the invention had sunk so low in public estimation that it was not thought worth paying the £50 stamp due at the expiration of three years on Mr. Mushet's large batch of manganese patents; they were consequently allowed to lapse and become public property.

The author has therefore used without scruple any of these numerous patents for manganese without feeling an overwhelming sense of obligation to the patentee.

At the suggestion of the author works for the production of manganese alloys were erected by Mr. Henderson at Glasgow, who now makes a very pure alloy of iron and manganese, containing from twenty-five to thirty per cent. of the latter metal, and possessing many advantages over spiegeleisen, which it will doubtless replace. Two bright rods of $1\frac{1}{2}$ inch diameter were placed on the table, they were folded up cold under the hammer. This extremely tough metal is made by

using Mr. Henderson's alloy in lieu of spiegeleisen, which is incapable of making steel of such a quality.

A Prussian gentleman, Herr Prieger, has been also successful in manufacturing a new alloy, which he calls ferro-manganese, consisting of sixty to eighty per cent. of metallic manganese. It is extremely useful in making malleable iron by the Bessemer process, in which spiegeleisen cannot be employed on account of the large proportion of carbon it contains.

It is gratifying to turn from a review of the troubles and impediments of the past and briefly notice some of the more important applications of steel as a substitute for wrought iron.

In no case is this change of material more important than in the construction of ships, for in no instance are strength and lightness more essential.

The Bessemer cast steel made for ships' plate by the several eminent firms now engaged in that manufacture is of an extremely tough and ductile quality, while it possesses a degree of strength about double that of the inferior kind of iron plates usually employed in shipbuilding, hence it is found that a much less weight of material may be employed, and at the same time a greater degree of strength may be given to all parts subjected to heavy strains.

Most prominent among the builders of steel ships is the firm of Jones, Quiggin, and Co., of Liverpool, who have now constructed no less than 31,510 tons of shipping, wholly or partially built of steel. Of these thirty-eight vessels are propelled by steam with an aggregate of 5910 horse-power; besides this the principal masts and spars of eighteen sailing ships have been made by them wholly of steel.

Vessels of a large size, constructed to Class AA twelve years at Lloyd's, weigh, when built of iron, about 12 cwt. per ton measurement, whereas similar vessels built of steel weigh only about 7 cwt. per ton measurement; thus an iron ship, to take first-class at Lloyd's for 1000 tons measurement, would weigh 250 tons more than a steel one of the same class. Such a vessel could therefore take 250 tons, or 25 per cent., more freight at the same cost, or could avail herself of the difference of immersion to leave or enter port when the tide would not permit an iron vessel to do so. As a steamer she would carry 250 tons more of coal, and thus be enabled to lengthen her voyage or take her coal for the return trip. The two steel paddle-wheel steamers launched at Liverpool by Messrs. Jones and Co., on the 13th ult., for Dublin and Liverpool service, will draw from 3 feet to 4 feet less water than iron steamers built on the same lines; and being thus enabled to leave port at all states of the tide, will not require a tidal train in connexion with them. If the employment of steel for the construction of merchant vessels is found to be so important, how much more so is it for ships of war? Some of the larger class of armour-plated vessels require 6000 tons of iron for their construction, and an addition of 1800 tons in the shape of $4\frac{1}{2}$ -inch armour plates. Now, if the frames and inner skin of such a vessel were constructed of steel, it would be much stronger even if reduced to 4000 tons in weight; this would admit of 9-inch armour plates being used in lieu of $4\frac{1}{2}$ -inch, and would still leave the vessel 200 tons lighter than the present ones, and hence, as the resistance of the armour to impact is as the square of the thickness of the plate, we should have a vessel capable of resisting four times the force of those at present constructed, while it would be 200 tons less in weight.

These important facts have not escaped the attention of Mr. Reed, our present talented constructor of the navy, and we shall doubtless soon have substantial proof of what may be effected by the employment of steel in the construction of ships of war.

The application of steel for projectiles has now become a necessity since the introduction of armour plates. We have before us a 110-lb. shot that has passed with very slight injury to itself through a 5-inch armour plate, and also some specimens of bent angle-iron, made of Bessemer iron, and rolled at the Millwall Iron Works in London, and from the same works a portion of one of Hughes's patent hollow steel beams for supporting the armour plating in course of construction for the forts at Cronstadt: both these are interesting examples of what the rolling mills of the present day can effect, and of the facility with which cast malleable iron and cast steel admit of being worked into the most difficult forms.

There is no department in engineering in which the peculiar toughness of steel and its strength and power of resisting wear and abrasion are of such vital importance as in its application to railway purposes. This fact had long since impressed itself strongly on the mind of Mr. Ramsbottom, of the London and North Western Railway, who commenced experiments with this material in 1861; carefully, though trustingly, he tried it step by step, not even at first venturing to employ it for passenger trains, but as proofs of its safety and economy crowded upon him, he carefully applied it to the most important parts of passenger engines, and even to the manufacture of the formidable engine cranks (at the time entrusted only to the most eminent iron-making firms in the kingdom); these iron cranks are now being replaced by steel ones forged from a single mass. One of these steel cranks, manufactured at the new steel works at Crewe, has been obligingly lent by Mr. Ramsbottom as an illustration of the use of steel for this purpose; that gentleman has also taken out of use a plain steel axle that has run a distance of 112,516 miles, and now exhibits very slight signs of wear.

The tires of wheels, on which so much of the public safety depends, were then tried, but the exact amount of difference between the endurance of wrought iron and Bessemer steel for this purpose is not yet ascertained, as none of these steel tires are yet worn out; but enough has been shown to prove the advantage of entirely replacing iron by steel for this purpose.

In order to show how a steel tire will resist the most violent attempts to produce fracture, an example is given of a steel tire manufactured by Messrs. Bessemer and Co., of Sheffield; it was placed on edge under a six-ton steam-hammer, and subjected to a series of powerful blows until it assumed its present form, that of a figure of eight, a degree of violence immensely more than it could ever be subjected to in practice. These tires are made without weld or joint, by forging them from a square ingot partly under the improved plan invented by Mr. Ramsbottom, and partly by an improved mode of flanging and rolling, invented by Mr. Allen, of the Bessemer Steel Works, Sheffield.

So important were found to be the advantages of employing cast steel as a substitute for wrought iron at the works of the London and North Western Railway Company, that the directors, acting under the advice of their able engineer, determined on building large steel works at Crewe, which are now in active and successful operation. In the design and arrangement of their plant for working up the steel several important improvements have been introduced by Mr. Ramsbottom, among others his duplex hammer, which strikes a bloom on both sides of the ingot at once, in a horizontal direction, and thus renders unnecessary the enormous foundations required for ordinary hammers. Here also he has put up his improved rolling mill for rolling blooms of large size, the enormous machine being reversed with the greatest rapidity and ease by the attendants, without any shock or concussion whatever.

While matters were thus steadily progressing in the engine department of the Company, the engineer of the permanent way, Mr. Woodhouse, took in hand a thorough investigation of a no less important problem, viz., the substitution of cast steel for wrought-iron railway bars. For this purpose some 500 tons of rails were made, and put down at various stations where the traffic was considerable, so as to arrive, at the earliest period, at a true comparison of the respective endurance of wrought-iron and cast-steel rails. It will be unnecessary here to enter into the numerous details of the extensive series of experiments systematically carried out by Mr. Woodhouse; the trials made at Camden will suffice to show the extraordinary endurance of steel rails. It is supposed that there is not one spot on any railway in Europe where the amount of traffic equals that at the Chalk-farm bridge at Camden Town. At this spot there is a narrow throat in the line, from which converges the whole system of rails employed at the London termini of this great railway. Here all passenger, goods, and coal traffic have to pass; here also the making-up of trains and shunting of carriages is continually going on. At this particular spot two steel rails were fixed on May 2nd, 1862, on one side of the line, and two new iron rails were on the same day placed precisely opposite to them, so that no engine or carriage could pass over the iron rails without passing over the steel ones also. When the iron rails became too much worn to be any longer safe

for the passage of trains, they were turned the other way upwards, and when the second side of the iron rails were worn as far as the safety of the traffic would allow, the worn-out rail was replaced by a new iron one—the same process being repeated as often as was found necessary. Thus we find, at the date of the last report on March 1st, 1865, that seven rails had been entirely worn out on both faces. Since then another rail has been worn out up to July, making sixteen faces worn out, the seventeenth face being in use on August 22nd, when the steel rail that had been placed opposite to them was taken up in the presence of the writer, and, by the kind permission of Mr. Woodhouse, was placed on the table before the meeting. The first face of the rail only has been used, and this is now become much thinner than it was originally, but, in the opinion of the platelayers, is still capable of wearing out another half dozen faces. Taking its resisting powers at three more faces only, it will show an endurance of twenty to one in favour of steel.

Mr. Woodhouse has ascertained, by careful and continued testing for twenty-four hours at a time, that an average of 8082 engine tenders or carriages pass over the steel rails every twenty-four hours, equal to 16,164 wheels every day for 1207 days, making a total of 9,754,974 wheels passed over the rail. Subject to this excessive wear, the rail appears to have been reduced $7\frac{1}{2}$ lbs. per yard, hence for every grain in weight of steel lost by abrasion, no less than 371 wheels had to pass over it. Another steel rail, put down also in May 1862, at a place much less subject to wear, has had four faces of iron rails worn out opposite to it, and still appears as if very little used; this rail was also placed on the table. An iron rail wears out by the giving way at various parts of the imperfectly welded mass, and not by the gradual loss of particles of metal, as in the case of the steel rail, which no amount of wear and tear seems capable of disjoining. It must be borne in mind that this enormous endurance of cast steel is not owing to its hardness or brittleness, as some have supposed, for, in fact, Bessemer steel possesses an extreme degree of toughness. There was before the Meeting an example of this fact; one of the same quality of steel rails having been attached at one end to the main driving shaft of a steam-engine so as to twist it while cold into a long spiral, measuring 9 feet in length at top and bottom, and only 6 feet if measured along the centre of the web. A single glance at this spiral rail will, it is presumed, dispel any idea of brittleness that may have been entertained.

In conclusion it may be remarked that cast steel is now being used as a substitute for iron to a great and rapidly increasing extent.

The jury reports of the International Exhibition of 1851 show that the entire production of steel of all kinds in Sheffield was, at that period, 35,000 tons annually, of which about 18,000 tons were cast steel, equal to 346 tons per week; the few other small cast-steel works in the country would probably bring up this quantity to 400 tons per week as the entire production of cast steel in Great Britain. The jury report also states that an ingot of steel, called the 'monster ingot,' weighing 24 cwt., was exhibited by Messrs. Turton, and was supposed to be the largest mass of steel ever manufactured in England. Since that date a great change has been made, for the largest Bessemer apparatus at present erected in Sheffield, at the works of Messrs. John Brown and Co., is capable of producing with ease every four hours a mass of cast steel weighing 24 tons, being twenty times larger than the 'monster ingot' of 1851.

There are now seventeen extensive Bessemer steel works in Great Britain. At the works of the Barrow Steel Company 1200 tons per week of finished steel can easily be turned out, and when their new converting-house, containing twelve more five-ton converters, is completed, these magnificent works will be capable of producing weekly from 2000 to 2400 tons of cast steel. There are at present erected and in course of erection in England no less than sixty converting vessels, capable of producing from three to ten tons at a single charge. When in full and regular operation these vessels will be capable of producing 6000 tons of steel weekly, or equal to fifteen times the entire production of cast steel in Great Britain before the introduction of the Bessemer process. The average selling price of this steel is at least £20 per ton below the average price at which cast steel was sold at the period mentioned. With the present means of production, therefore, a saving of no less

than £6,240,000 per annum may be effected in Great Britain alone even in this infant state of the Bessemer steel manufacture.

Weldless Tyres, Circular Rolling, and Railway Wheels.

By F. I. BRAMWELL.

The paper was not intended for engineers only, but was also addressed to those who are not intimately acquainted with the details of the manufacture of tyres and wheels as hitherto pursued.

The paper gave an account of some of the principal modes employed in the manufacture of tyre hoops prior to the use of weldless tyres, and pointed out the defects of those modes, and alluded to plans that have been adopted to prevent accidents arising from their use.

The paper then gave a description of the means by which weldless tyre hoops are now made by some manufacturers, referred to Bodmer's circular rolling, and entered into the details pursued in working tyre-making machinery principally designed by the writer.

The paper then referred shortly to the manufacture of steel tyres by circular rolling, and showed that that mode of rolling is applicable to the making of boilers and other articles.

The paper then considered the question of making straight or level or flat bars, rails, or plates, by the use of circular rolling in the first instance to form a hoop, which hoop is to be cut open and laid out flat to make the bar, rail, or plate.

The paper then referred to the principal kinds of railway wheel-centres in use, and stated the nature of Arbel's improvement in the manufacture of entire wrought wheel-centres, and Lahousse's mode of making an economical wrought wheel-centre, which is arrived at by dispensing with the necessity of requiring the spokes to be got to a welding heat, and described how these modes of Arbel's and Lahousse's are practically used.

The paper was illustrated by several diagrams.

On Railways in War.

By General Sir J. F. BURGOYNE, Bart., G.C.B., D.C.L., F.R.S.

The paper opened by stating that railways would have an important effect on war, and that it was a matter of interest to ascertain the means of obtaining the greatest advantage from them, and what would be their precise capabilities. A vague idea existed that armies could be transported from place to place and to a seat of war with the same facility and speed as ordinary travellers, whereas there were many circumstances connected with the conveyance of the former which would show any such comparison to be quite fallacious. With regard to a small body of infantry, there was no reason why this should not be the case; but with large forces, and with cavalry and artillery, and all the accessories of an army, its baggage, camp equipage, spare ammunition, its waggons, &c., enormous means would be required, and difficulties would arise which called for study and consideration to reduce them to a minimum. How to adapt the ordinary railway passenger and horse carriages and trucks in the best manner to the transport of troops of all kinds, and how to get the troops most rapidly in and out of them, would be easily ascertained, if it had not been so already; the great desideratum was to define how large forces could be moved in greatest strength, with the most rapidity, on single railways or by a limited number of lines; for it was on these calculations, having under consideration the several lines which could be brought to bear on the operations, that the generals in command must arrange their plans. The basis for consideration would be: What could be done by any one line of railway with its ordinary means, or aided by additional means from other lines of the same gauge with which it was connected, on the same level, and which might not have the same pressure on them? To afford an idea of what might be required, it might be assumed that the officers and soldiers would occupy the space of ordinary travellers, and consequently it would become a question how many passenger carriages, in how many trains, each drawn by one locomotive, would be required to convey 1000 men,

with their officers; and how many horses of cavalry, artillery, and for staff of infantry regiments, one truck would carry. The guns and equipments of each battery of field-pieces, with number of trucks necessary to carry them, should be defined, as well as the number of horses per battery of horse or foot artillery. To give an idea of the amount of conveyance required for such forces, on one occasion, to transport a battery of field-pieces, with its horses and carriages, and about 500 cavalry, merely to a review, no less than six trains were required, consisting each of thirty railway carriages. Viewing the very large means necessary for moving any but a very moderate force, the embarrassments which would attend the undertaking, and the rapid succession required to be effective, it became a matter of much interest for railway engineers to consider and define how arrangements could be made in providing, stationing, and working the trains that would tend to facilitate the service, and what, with the adoption of these measures, would be the capabilities of conveyance of troops of given strength to given distances in given times on emergent occasions on any one railway; whether, for instance, as the great traffic would be in one direction, both lines of rails might not be used for it for certain distances, under the best arrangements which can be made for the return of carriages, &c. These researches are required not only to ascertain the best modes of accelerating the movements, but also to come to a clear understanding as to what, even when duly organized, can be obtained from railways in rapidity of transport for large bodies. It is manifest that, as they approach the scene of action, the railways would have less influence on the immediate theatre of warfare itself; it would be somewhat dangerous to trust to them at all under the chance of the enemy interrupting the communication between the divisions and resources of the army. For short distances there would rarely be much advantage, as regards time, in moving troops by them, on account of the time required for getting to and away from the railway, and into and out of the carriages. Their great advantage would be for concentrating troops and means, by converging lines, from the interior to some appropriate point forming a basis of operations; for gradually bringing up reinforcements and other resources to the rear of the army; and for the speedy and better removal of sick or wounded, prisoners, and all incumbrances. They would also be particularly favourable to retreating forces, by expediting their movements; while, by the destruction of the lines behind them, the enemy would be deprived of any use of them. The partial destruction and the repairs to railways will hereafter be an engineering duty for which the service should be prepared.

Every railway, even in the vicinity of the operations in a campaign, will be of much value, so long as it can be used without danger of interruption, and therefore it becomes a subject of interest to possess a knowledge of the best means for their destruction, and how to apply them in cases where the lines are likely to fall into the hands of the enemy, or for reestablishing any that may have been more or less injured. It is clear that a portion of a railway might be for hours in temporary possession of a part of an army, who might, from ignorance, or want of some trifling means, be unable to take advantage of the occasion, and thus would leave it to be repossessed by its enemy in perfect order, when, by due instruction and a little preparation, an influential amount of damage might have been done to it. The military engineers of an army have attached to them in the field a selected assortment of the most useful implements for the different services most frequently required of them, the proportions of which they vary according to the prospect of the nature of the approaching engineering operations, such as for sieges, entrenchments, destruction or repairs of roads and bridges, mining, &c.; and they are practised in the best modes of applying whatever means may be at hand for their purpose. To these must now be added what is applicable to the destruction and reestablishment of railways. In damaging a railway to impede the progress and available means of an enemy's army, the object will of course be to do as little injury to a great convenience of the country as is consistent with the primary consideration of crippling the military resources of the enemy for the time. Should the exigencies of the period justify extensive damage, it will be done by blowing in tunnels, bridges, viaducts, or embankments, by mines and processes as practised by military engineers, with regard to the old routes, to the extent that circumstances will allow and may admit. The object for consideration, however, here is, how the peculiarities of a

railway can be dealt with to most effect, in a summary manner, with little time and small means. Taking it, then, as a question rather of dismantling than of destroying, the first measure would be the taking up and destroying of the rails. This would be easy enough to a party of railway navvies provided with their apparatus; but what we require is, some instructions and practice given to soldiers how to do as much as possible with the smallest means. Thus, instead of being, as at present, from ignorance, perfectly helpless, they might be taught, under previous instruction, that even a few stray articles for implements, such as might be found in an adjoining house, as might be described, could, on an emergency, be made available to some extent. Possibly it could be shown that, after a first rail was removed, the very article itself, with the sleepers, &c., might be used to extend the damage. Another question would be, having in view the possibility of obtaining a temporary power over a railway which is of service to the enemy, what very small and most portable assortment of implements might be carried with any detachment, being accompanied, if possible, by a few Sappers that would aid such a proceeding, and what would be the most effective process; and if the implements could be such as enter into the assortment forming part of the engineer field-equipment, required for other purposes, all the better. The rails being raised, the best disposition of them would be clearly to carry them away altogether; but it is very improbable that there would be available means of conveyance to render that practicable. The next most easy resource would be to scatter, hide, or bury them; but if it could be shown how they could be broken or rendered unserviceable, the effect would be still greater. The destruction of the sleepers would be much more easy, but the effect would be less, and the removal of the chairs, from their portability, would be easy, and also valuable for the object. With regard to the reinstatement of a damaged line, it would be instructing to know whether any temporary expedients could be adopted for the passage of locomotives and carriages, or even of the carriages only, across the places where the rails may have been removed, till new rails can be procured; and, if so, what those expedients may be, and how to be applied. One resource might be available in double lines, namely, to dismantle one of the double rows, from the nearest part untouched, to make good a thorough communication for at least one single line. It will be very desirable to obtain from railway engineers a consideration of all these matters, and special instructions drawn up on all expedients that can be suggested, in which the troops, but more particularly the engineer soldiers, might be subsequently practised; nothing of the kind, it is believed, having yet been undertaken.

On a Pneumatic Hammer. By G. BURT.

This hammer does not approach the power of a steam-hammer of the same total weight, nor would it take the place of the steam-hammer for general smith's work. The advantages claimed for it were that it was very simple, especially in its single-acting form, as shown by a model; that there were no valves in constant motion and wear; that the momentum of the driving parts connected with the crank-shaft was very small, on account of their small extent of motion (a throw of 1 inch only being given to the 10-inch piston); that the wear on these parts was consequently very slight, also owing to the elastic nature of the medium between the driving and driven pistons; that there was an absence of all dropping of condensed steam, such as would invariably be caused by the use of a steam-hammer.

On Torbite (a new Preparation of Peat) and its Uses. By D. K. CLARK.

The object of the paper was to describe the system pursued at Horwich, near Bolton, for the manufacture of torbite and charcoal from peat. The obstacles hitherto to treating peat for the manufacture of fuel were shown to consist chiefly in the difficulty of separating, at a moderate cost, the excessive proportion of water held in suspension by peat in its natural condition, in consequence of the uncertainty of the climate and the great amount of hand-labour employed, and in the impossibility of efficiently condensing and solidifying peat by mechanical compression, which has been the agency relied on for that object. The author then explained that, according to the Horwich system of treatment, compression by

mechanical force in any manner is studiously avoided; and that, on the contrary, advantage has been taken of the natural property of peat, suitably prepared, of contracting as it parts with its moisture, and becoming perfectly solid and cohesive. To separate the water, the peat travels upon endless bands, within a close chamber, exposed to currents of heated air, by which the moisture is effectually extracted; the blocks of peat being turned up on all sides in succession, so as to be equally and regularly dried, and emerging dry, hard, and dense. To the peat substance thus prepared the name of "torbite" has been given; and it was stated that it could be delivered at a cost of from 10s. to 12s. per ton. In the subsequent stage, the conversion of the torbite into charcoal, it was pointed out that the fatty and other matters disengaged during the charring process were valuable commercial products, the sale of which alone would nearly cover the cost of the whole process. Some experiments were described, proving the suitability of torbite and its preparations for purposes of generating steam and smelting iron ore, and in the other stages of the manufacture of iron. It was contended, therefore, that the problem of the probable utilization of peat had at last been solved. It was stated, in conclusion, that the bogs of Great Britain and Ireland cover an area exceeding five millions of acres, the average depth of which might be taken at twenty feet; and that the benefits of the utilization of peat on the large scale, particularly for Ireland, could scarcely be over-estimated from an industrial point of view.

On a Machine for stitching Button-holes. By J. M. CLEMENTS.

The paper stated that the almost universal adaptation of the sewing-machine to manufacturing as well as domestic purposes, had given rise to a demand for a machine for working button-holes, most of the large manufacturing clothiers in England and the shirt-makers in Belfast and other towns of Ireland having for several years expressed their desire for, and great want of, such a machine. Having noticed the various attempts made to produce a button-hole stitching machine, the paper described that introduced to notice by the writer, and proceeded to point out that it could be applied, not only to fine work, but also to heavy work, such as sail-making, railway sheets, or carpet-making. The machine would work sixty or seventy holes per hour, both sides alike, and with a lock stitch.

On a new Cotton Gin for separating Cotton Fibre from the Seed.

By E. A. COWPER.

This gin is composed of a roller having strips of leather on its surface at intervals, and strips of pointed surface between them; the roller revolves continuously, and there is a blunt steel blade, which is caused to approach the roller, and recede from it at intervals, by means of eccentrics, which also move it up and down both in the direction of the surface of the roller and in the opposite direction. In addition to this roller and blade there is a vibrating beater to push off the seeds, this last action being very similar to the motion of a beater in a MacCarthy gin. The eccentrics are on a small crank-shaft that moves the beater, and which has a pinion on it, driven by a wheel on the roller-shaft. This gin differs from all others in its complete intermittent action, and it also acts on an entirely new principle, viz., that of *nipping fast hold* of the cotton-fibre *close up to the seed* (just as it might be taken fast hold of by a person's finger and thumb) whilst the seed is separated. The steel blade recedes from the roller when fibre is entering, and then nips upon it and *holds it fast close up to the seed* whilst the beater pushes off the seed. In consequence of the fibre being thus locked fast in the jaws it has been called the "Lock-jaw Gin," one side of its jaws being formed of the strips of common leather on the roller, whilst the jaw on the other side is formed of the blunt steel blade, caused to approach the leather surfaces when nipping by means of eccentrics. This machine does its work so effectually and quickly that it gets through several times as much work as a common "MacCarthy gin" can, and many times as much as an "Indian Churka," and at the same time gives a decidedly increased length of staple from a given sample of cotton. This new principle of action in separating cotton-fibre from seed, promises to cause as great a change and improvement in ginning cotton as Heilmann and Lister's invention did in the combing of

wool, as the work is done better than by a MacCarthy gin, and nearly as quickly as by a Saw gin, and it is thus particularly valuable in reference to the *short stapled* cotton of India, and the long stapled cotton of Egypt.

On the Effect of Blowing Blast Furnaces with Blast of very High Temperatures. By E. A. COWPER.

Very satisfactory results were obtained in 1860-1861 from a pair of Cowper's hot-blast stoves, heating the blast to a particularly high temperature for one tuyère only for a blast furnace (the other four being blown with ordinary hot blast). These stoves were for a length of time in successful operation at Messrs. Cochrane and Co.'s works at Ormesby, near Middlesborough-on-Tees; these gentlemen then erected large stoves to supply blast of very high temperature for a whole furnace, which stoves have now been in full operation for upwards of four years with the following satisfactory results, viz. an increased "make" of iron from the same plant of fully 20 per cent., the iron being of rather improved quality, owing to less impurity being carried in with the fuel, the avoidance of all leakage caused by the ordinary cast-iron pipes, reduced friction or loss of pressure in the blast passing through the stoves, and a saving of upwards of five hundredweight of coke per ton of iron made, the blast being at 1150° Fahr. These stoves are the invention of Mr. E. A. Cowper, who has adopted the regenerative principle invented by Mr. Siemens, as the means of absorbing the heat from the products of combustion and giving it out again to the air to be heated, the regenerators being each enclosed in an iron casing lined with firebrick, and provided with valves to allow of the passage of ignited gas through the stove to heat it, and valves to allow the entrance of the cold blast and exit of the hot blast. The stoves are heated by the combustion of gas obtained from gas producers, such as are now used largely for Mr. Siemens's glass furnaces; but recent experiments have been made, with the view of separating the gas from the top of the blast-furnace, from the dust it commonly contains, so that such gas may be conveniently used, and it has been found that it is only necessary to cause the gas to travel for some distance at a speed of less than 1 foot per second in thin layers, in order thoroughly to deposit all the dust contained in it; and by arranging a number of thin shelves at a small distance apart, and at an incline in a large pipe or box, the dust deposits on the shelves, and can be easily washed out occasionally with great facility by a stream of water, blast, or steam.

On Siemens's Regenerative Gas-Furnaces and Producers. By S. N. F. COX.

The author commenced by stating that the system of regenerative gas-furnaces having now been before the manufacturing world for several years, and having been employed for the manufacture of glass of all kinds, iron, and steel, and nearly every other article in the production of which great heat was required, and having proved in nearly every case successful, it had ceased to be an experimental system, and had become an established and recognized success. The paper then described, by the aid of diagrams, the construction of the furnace in which the gas was burnt, and the gas-producers for all descriptions of fuel. By this process a flame was obtained (equal to a white heat) which did not contain anything that could injuriously affect the most delicate manufacture, for even sulphuring was prevented, for the sulphur in separating from its hydrogen took up oxygen supplied by the carbonic acid and water, forming sulphurous acid,—a stable compound, which was not decomposed on meeting metallic oxides in the furnace. The nature and intensity of the flame was also under the instant control of the man in charge of the furnace, so that the chemical nature of the flame could be altered at will—one minute an oxidizing flame being obtained, and the next a reducing or carbonizing one. So also the amount of the flame could be altered from the smallest flicker to the complete filling of the chamber with an intense body of flame. The paper pointed out the immense advantage thus obtained in furnaces where the delicate operation of heating or melting steel was carried on; and for reheating purposes, especially for reheating steel blooms and ingots. The advantage of the system was a large saving of fuel. A ton of steel by the furnace was melted with an average weight of a ton

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of coal, instead of two and a half to three tons of coke, which represented six to seven tons of best coal. With such names before them as Meyer, Borsig, and Krupp, as employers of Siemens's furnaces for steel melting, it did little credit to English enterprise to say that there was hardly one furnace in England in constant work for steel melting. Besides the saving of fuel, there were other advantages in the working of the furnace, such as cleanliness, no solid fluid being brought into the shop where the furnaces were, the fuel being converted into gas at any convenient distance from the furnaces; compactness of arrangement, saving of labour, and, above all, improvement in the processes themselves. In every trade in which the furnace might be employed, the same advantages were apparent; and though the furnaces were costly, and required a large outlay at first, especially in old works, they soon paid for themselves.

On some of the Causes of the Failure of Deep-sea Cables, and Experimental Researches on the Permanency of their Insulators. By WILLIAM FAIRBAIRN, F.R.S.

The author stated that the recent disaster and loss of the greater portion of the Atlantic cables is one of those casualties which may be considered national, and looked upon as a misfortune much to be regretted. It is, however, suggestive of improvements and the removal of impediments which seem to have beset the last attempt to submerge what was considered the best and most effective cable ever constructed for a durable telegraphic communication between this country and America.

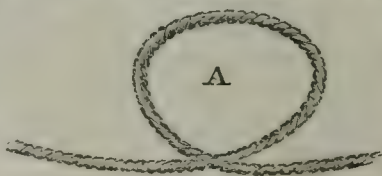
This cable was unanimously selected by the scientific committee, to whom was entrusted a long series of experiments to determine its strength and other chemical and electrical properties of the materials of which it was composed. These will be found in a former Report in the Transactions of last year, pages 408 *et seq.*

It will be noticed that the late failure of the insulation, submergence, &c., is not an uncommon occurrence; on the contrary, it has been estimated that out of about 14,000 miles of cable that have been laid, nearly three-fourths of that length have been failures, and that at the present time not more than from 4000 to 5000 miles are in successful operation.

There are two things in marine telegraphy which require special attention, viz., the manufacture of the cable, and its submergence in deep water. In this inquiry the author ventures to assume that the conducting wires, insulation, and strength of the cable were satisfactory, and nothing more remained to be done than to lay it quietly on the bed of the ocean. The recent loss of this cable, and the imperfect insulation of others, are, however, important lessons, which prove the necessity of the most vigilant inspection of every inch of cable as it is manufactured in the first instance, and its careful preservation until it is safely deposited in the bed of the ocean in the second. Every possible care was in this case taken; but, notwithstanding the precautions exercised by the manufacturing company, small pieces of wire on three different occasions were found sticking in the cable in contact with the conducting wires and destructive of the insulation. These apparently trifling circumstances were the whole and sole cause of the loss the Company and the public have sustained in the failure of this important enterprise.

A voyage from the Nore to Valencia in July last presented opportunities for examining the big ship with her machinery and valuable cargo. The paying-out machinery was perfect, as it proved itself to be in regard to its powers for regulating the slack to be paid out at different depths, and the uniform degree of tension requisite to be observed in paying out the cable at great depths.

Paying out a cable of considerable weight and strength from the coil seems to be surrounded with many difficulties, the greatest of which is the danger of kinks arising from the twist which it receives in being uncoiled. This is the great objection to every description of cable payed out from the coil, as the tendency is to run into loops, such as shown at A, and this, when submitted to an amount of ten-

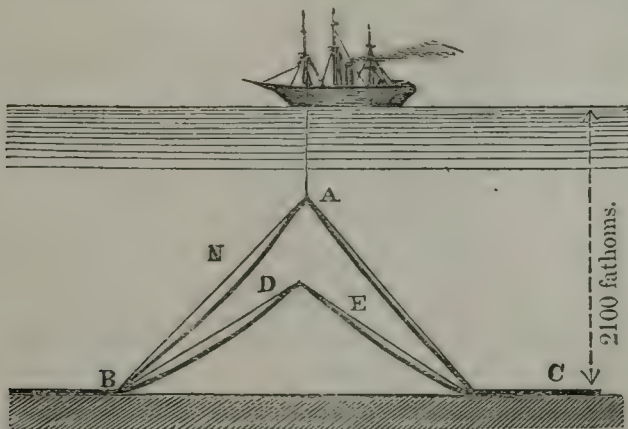


sion of not more than one-half its ultimate powers of resistance, would injure the insulation, and what is more than probable, would ultimately destroy the conductivity of the cable. These are difficulties which in this weight of cable and large diameter of coils in the tanks has been overcome. With a smaller cable (carefully insulated) depending entirely upon the conducting wires for its strength, it would be possible to wind it in lengths of 80 to 100 miles upon reels, and these, neatly balanced in the hold of the ship, might be paid into the sea entirely free from kinks; but in doing this it must be observed that considerable risk is incurred of breaking the cable from the amount of friction to which the wheels would be subject when loaded with 80 miles of cable. Taking the whole conditions of these arrangements into account, it is not clear that the reels would be any improvement upon the large coils in tanks, as adopted in the 'Great Eastern' ship. In fact there is no other plan suitable for the paying out of the Atlantic cable of its present weight and dimensions but the coil.

With regard to the 'Great Eastern' ship, he stated that she proved herself everything that could be wished for. Her easy steady motion was just what was required for paying out the cable, and its relief from undue strain by the absence of pitching renders the ship exclusively calculated for the submergence of submarine cables in deep water. She is the very thing that is wanted for such a purpose, and he firmly believed, if she was properly fitted and prepared for such a service—with some additional stringers to strengthen the upper deck and sides—she would find full employment as a submerger of cables in every sea which divides the four quarters of the globe. She is admirably adapted for such a purpose, and her double engines, with screw and paddles, assist the steering, and afford great facilities for paying out and hauling in the cable should accidents occur such as overtook the vessel in the middle of the Atlantic.

The author further remarked that the recovery of a lost cable is at all times a precarious operation, and the difficulties which present themselves in the case of the Atlantic cable, are its large diameter and the friction of its external surface in passing through the water. If raised at all it must be at an exceedingly slow speed, and that with one end loose, otherwise he should despair of raising it from a depth of 2100 fathoms, by hooking it in the high or middle, where the resistance would be doubled in raising two sides instead of one.

Supposing the cable to be hooked by the grapnel at a few miles distant from the fracture, it will then be seen (if it is to be raised from a depth of $2\frac{1}{2}$ miles) that the present cable would have to be lifted at an angle of about 45° on each side, or 3.18 miles of cable $= 6.25 \times 14$ cwt. (the weight of the cable in water), a weight of $4\frac{1}{2}$ tons, or equivalent to more than one-half the breaking strain. To this dead weight must be added the friction of the two sides of the triangle AB and AC,



which will be as the squares of the velocities with which it is raised. What may be the additional amount of strain from the speed with which it may be drawn through the water it is not necessary here to calculate, as it is obvious that at a

velocity of two miles per hour it would approximate close upon the breaking weight of the cable.

Assuming, for the sake of calculation, that the strain, including weight and friction, to be 6 tons, and as it requires a strain of $7\frac{3}{4}$ tons to break the cable, there is left in reserve $1\frac{1}{4}$ ton to carry the bight of the rope to the surface of the water. Now this is assuming that the cable has been paid out with as much slack as will enable it to be raised in the manner just described; but this is evidently not the case, and as any attempts at raising the cable in this form would break it, the slack of 1100 yards on each side would require to be taken up, and a drag for 5 miles on each side would be the result, before it could reach the surface. This is evident from the fact that the excess of cable paid out over the distance run was 1210 : 1060, or $12\frac{1}{2}$ per cent. of slack. This would be equivalent to dragging some miles of cable through the ooze or mud to make up the difference between the catenaries D, E, and AB, AC.

According to this reasoning, it would appear that any attempt to raise the cable in this way would prove fruitless unless some means were adopted to cut it at the point N on the American side, and haul in by a second grapple which would hold fast until the cable was brought to the surface*.

In the construction of submarine cables, he observed that their success depends on such a variety of circumstances—some of them exceedingly precarious—that the wonder is they have succeeded so well as they have done. In the manufacture of a marine cable there is no difficulty with the conducting wire, if made of pure copper; but the greatest care and caution is required to be taken with the insulator to see that the different coats of gutta percha are pure, solid, and free from injury by the abrasion of the external covering when composed of strands of wire, constituting the strength of the cable.

The following experiments were instituted by the author at the request of the Commission, with a view to determine how far the different kinds of material proposed as insulating coverings for electric submarine cables were reliable when placed at the bottom of the ocean under the pressure of the superincumbent water.

Generally in regard to the insulating powers of the various materials tried, they seem to arrange themselves in the following order of permeability, the first absorbing least water, and the last absorbing most :—

- | | |
|-----------------------------|-------------------------------|
| 1. Chatterton's compound. | 5. Carbonized india-rubber. |
| 2. Gutta percha. | 6. Wray's compound. |
| 3. Masticated india-rubber. | 7. Unmasticated bottle india- |
| 4. Vulcanized india-rubber. | rubber. |

The experiments on the insulating powers of various cores under pressure are less complete than those on absorption, and have been prosecuted under greater difficulties and with less variety of conditions.

The first experiments have for their object the determination of the increase of weight of various insulating materials when subjected to enormous pressure under water.

* Since the above was written, the author has been in communication with the engineers and others connected with the Construction and Maintenance Company, who are now constructing an entirely new cable similar to that of last year, excepting only that the iron wires are galvanized, and the hemp covering is not saturated with tar. This new cable will be attached to the shore ends at Valentia and Newfoundland; and should this expedition be successful, the 'Great Eastern' and her two consorts will be enabled to return to the spot where last year's cable parted, and by the usual means of grapnels to fish it up, and splice to it as much of the new cable as will carry it forward to Newfoundland. Thus it is confidently expected that two cables will be the important result of this year's undertaking. Considerable difference of opinion appears to exist as to the ultimate success of these critical operations, but as every precaution is taken in having improved machinery for picking up and hauling in, under the direction of Mr. Canning, the Construction and Maintenance Company's Engineer, the prospect of success is much more encouraging than at any former period in the history of this important enterprise. It is moreover intended to employ two more vessels with proper apparatus for grappling the cable at those distinct spots, in order to relieve the strain and to hold by buoys until the cable is cut and hauled on board.

TABLE I.

First Series of Experiments on Absorption, under a pressure of 20,000 lbs. per square inch, reduced to 100 hours' exposure, and 10 inches area.

Reduced results.

| No. of Experiment. | Insulator. | Pressure, in lbs. per square inch. | Equivalent column of water, in miles. | Duration of exposure, in hours. | Area of specimen, in square inches. | Water absorbed, in grains. |
|--------------------|--------------------------------|------------------------------------|---------------------------------------|---------------------------------|-------------------------------------|----------------------------|
| 1. | India-rubber | 20,000 | 8·720 | 100 | 10 | 0·177 |
| 2. | India-rubber with carbon | 20,000 | 8·720 | 100 | 10 | 0·055 |
| 3. | Wray's compound | 20,000 | 8·720 | 100 | 10 | 0·072 |
| 4. | Gutta percha, ... | 20,000 | 8·720 | 100 | 10 | 0·044 |

The temperature in all these experiments was low, sometimes several degrees below the freezing-point. In the first experiment with Wray's compound, the cylinder when opened was found to be filled with loose ice.

In the next series the whole of the specimens were placed in the same cylinder, and remained under pressure during the same period, and under the same conditions.

TABLE II.

Experiments on Absorption, under a pressure of 6000 lbs., and at the ordinary temperature.

Reduced results.

| No. of Experiment. | Insulator. | Pressure, in lbs. per square inch. | Equivalent column of water, in miles. | Duration of exposure, in hours. | Area of specimen, in square inches. | Water absorbed, in grains. |
|--------------------|-----------------------------|------------------------------------|---------------------------------------|---------------------------------|-------------------------------------|----------------------------|
| 1. | India-rubber, unmasticated | 5900 | 2·575 | 450 | 10 | 3·075 |
| 4. | India-rubber, masticated.. | 5900 | 2·575 | 450 | 10 | 0·023 |
| 8. | " " .. | 5900 | 2·575 | 450 | 10 | 0·636 |
| 9. | " " .. | 5900 | 2·575 | 450 | 10 | 0·700 |
| 10. | " " .. | 5900 | 2·575 | 50 | 10 | 0·711 |
| 11. | India-rubber, vulcanized.. | 5900 | 2·575 | 450 | 10 | 0·146 |
| 7. | India-rubber, carbonized .. | 5900 | 2·575 | 450 | 10 | 0·980 |
| 2. | Gutta percha. | 5900 | 2·575 | 450 | 10 | 0·378 |
| 13. | " " | 5900 | 2·575 | 450 | 10 | 0·177 |
| 14. | " " | 5900 | 2·575 | 450 | 10 | 0·366 |
| 5. | Wray's compound | 5900 | 2·575 | 450 | 10 | 0·750 |
| 13. | " " | 5900 | 2·575 | 450 | 10 | 0·700 |
| 6. | Chatterton's compound .. | 5900 | 2·575 | 450 | 10 | 0·375 |
| 12. | " " .. | 5900 | 2·575 | 450 | 10 | 0·183 |

The order of merit in resisting absorption, as derived from this series of experiments, is—

- | | |
|-----------------------------|---------------------------------|
| 1. Vulcanized india-rubber. | 5. Wray's compound. |
| 2. Chatterton's compound. | 6. Carbonized india-rubber. |
| 3. Gutta percha. | 7. India-rubber not masticated. |
| 4. Masticated india-rubber. | |

The next series of experiments was made under greater pressure, but in the same manner and for the same period of immersion.

TABLE III.
Third Series of Experiments on Absorption at ordinary temperatures
Reduced results.

| No. of Experiment. | Insulator. | Pressure, in lbs. per square inch. | Equivalent column of water, in miles. | Duration of exposure, in hours. | Area of specimen, in square inches. | Water absorbed, in grains. |
|--------------------|----------------------------|------------------------------------|---------------------------------------|---------------------------------|-------------------------------------|----------------------------|
| 6. | Raw india-rubber. | 15,000 | 6·54 | 450 | 10 | 1·65 |
| 7. | Masticated india-rubber .. | 15,000 | 6·54 | 450 | 10 | 0·22 |
| 8. | " " .. | 15,000 | 6·54 | 450 | 10 | 0·29 |
| 9. | " " .. | 15,000 | 6·54 | 450 | 10 | 0·30 |
| 10. | Carbonized india-rubber .. | 15,000 | 6·54 | 450 | 10 | 0·29 |
| 5. | Gutta percha. | 15,000 | 6·54 | 450 | 10 | 0·18 |
| 1. | Wray's compound | 15,000 | 6·54 | 450 | 10 | 0·56 |
| 2. | " " | 15,000 | 6·54 | 450 | 10 | 0·58 |
| 3. | Chatterton's compound .. | 15,000 | 6·54 | 450 | 10 | 0·054 |
| 4. | " " .. | 15,000 | 6·54 | 450 | 10 | 0·058 |

The temperature during these experiments was generally lower than in the second series, being frequently at the freezing-point. There was loose ice in the cylinder when opened.

The order of merit, or power of resisting absorption, is in these experiments—

- | | |
|-----------------------------|-----------------------------|
| 1. Chatterton's compound. | 4. Carbonized india-rubber. |
| 2. Gutta percha. | 5. Wray's compound. |
| 3. Masticated india-rubber. | 6. Raw india-rubber. |

The last in this series absorbed twenty-seven times as much as the first; gutta percha and Chatterton's compound hold, as before, the highest place, but the superiority of the latter was more manifest; it had become whitened at the surface, but apparently the water had penetrated the thinnest possible film.

The next experiments were made with a view to determine the effect of temperature on the absorption of water by these insulators.

The different substances were tried separately, as in the first series, and the weighings were repeated at intervals. During the night it was necessary to remove the gas-jet, as the uniformity of temperature could not be depended upon; hence for half the period of immersion the specimens were at a temperature of 50° only, and for the remainder at a temperature of 100°. The loss of weight after removal

TABLE IV.
Fourth Series of Experiments on Absorption at increased temperatures.
Reduced results.

| No. of Experiment. | Insulator. | Pressure per square inch, in lbs. | Duration of exposure, in hours. | Temperature Fahr., mean. | Area of specimen, in square inches. | Water absorbed, in grains. | Loss of weight in drying. |
|--------------------|-----------------------------|-----------------------------------|---------------------------------|--------------------------|-------------------------------------|----------------------------|---------------------------|
| 3. | Gutta percha. | 20,000 | 100 | 75° | 10 | 0·27 | 3·61 |
| 4. | India-rubber | 20,000 | 100 | 75° | 10 | 0·45 | 0·87 |
| 5. | Wray's compound | 20,000 | 100 | 75° | 10 | 0·58 | 0·91 |
| 6. | Chatterton's compound .. | 20,000 | 100 | 75° | 10 | 0·20 | 0·60 |
| 7. | Vulcanized rubber | 20,000 | 100 | 75° | 10 | 0·80 | 2·27 |

from the cylinder, in consequence of the evaporation of the water absorbed, was in these experiments noted, and it was found the specimens decreased in weight below their original weight when dry.

In the whole of these experiments the pressure was 20,000 per square inch, area of specimens 8 square inches, and thickness about $\frac{1}{8}$ th of an inch.

TABLE V.

Summary of Results, showing approximately the time required in the case of each Cable for a loss of charge equivalent to a fall of the Electrometer Needle of 50°.

| No. of Experiment. | Description of core. | Pressure per square inch, in lbs. | Equivalent column of water, in miles. | Duration of exposure, in hours. | Time required for loss of 50°. |
|--|---|---|---|---|---|
| 1, 2.
3.
4, 5. | I. Gibraltar core cured by Mackintosh .. | 10,000
10,000
10,000 | 4.363
4.363
4.363 | 282
328
405 | 136 20
100 0
32 30 |
| 1, 2, 3.
4.
5, 6.
7.
8, 9.
10.
11, 12, 13. | II. Core impregnated with insulating liquid | 0
10,000
10,000
10,000
10,000
10,000
10,000 | 0
4.363
4.363
4.363
4.363
4.363
4.363 | 0
24
48
56
77
120
170 | 6 20
11 40
27 35
13 0
62 0
97 0
105 0 |
| 1, 2. | III. Wray's core | 0 | 0 | 0 | 1300 0 |
| 2. | IV. Wray's core | 0 | 0 | 0 | 411 0 |
| 2,
3, 4. | V. Core impregnated with insulating liquid | 10,000
10,000 | 4.363
4.363 | 4
10 $\frac{1}{2}$ | 68 30
44 15 |
| 1,
2, 3.
5.
6. | VI. Core of 20 alternate coats of gutta percha and Chat-terton's compound | 0
10,000
10,000
10,000 | 0
4.363
4.363
4.363 | 0
121
150
170 | 95 30
42 45
118 0
100 50 |
| 1.
2. | VII. Core of pure india-rubber | 0
10,000 | 0
4.363 | 0
80 | 443 0
18 0 |
| 1, 2,
3.
4, 5, 6.
7, 8. | VIII. Gutta percha core | 0
10,000
10,000
10,000 | 0
4.363
4.363
4.363 | 0
264
480
576 | 4 30
8 0
4 5
3 37 |
| 1.
2. | IX. India-rubber core | 0
3977 | 0
1.72 | 0
390 | 26 0
0 0 |
| 1.
2.
3. | X. Silver's india-rubber core | 0
0
0 | 0
0
0 | 0
0
0 | 380 0
387 0
382 0 |

Comparing the numbers in this Table with those in the first series, it becomes evident that temperature has a considerable effect on the amount of water absorbed. Thus gutta percha at 45° F. absorbed 0.044 grain, at 75°, 0.27 grain, or six times

as much. In like manner, india-rubber absorbed 0.177 grain at a lower temperature, and 0.45 at a higher, or two and a half times as much. Wray's compound 0.072 at a lower temperature, and 0.58 at the higher, or seven times as much.

In the earlier experiments the insulating power of the various cores was tested with voltaic electricity. In the following series, however, recourse was had to frictional electricity, which from its high intensity passed with greater or less facility through the insulating coverings of the wire. In the former, the measurement and regulation of the charge, and the rate of loss were made with a double pith-ball electrometer; in the latter, or fifth series, a Peltier's electrometer was employed.

The charge was given from an electrophorus, and was ordinarily of such intensity as to deflect the needle through an arc of 70°. The fall of the needle was watched at intervals till it had sunk to 20°.

On a careful inspection of the above summary, it will be seen that a great difference exists in the retentive powers of the different cores or insulators under severe pressure, which in these anomalies almost defy attempts at comparison. The experiments are, however, satisfactory, in so far as they show approximately the relative porosity of various materials; but they do not point out how we are to obtain an insulator impermeable to water, and at the same time a good non-conductor. This desideratum has yet to be attained.

Suggestions for Improvements in Blocks for Lowering Ships' Boats, and for Improvements in Boats. By GEORGE FAWCUS.

Blocks were exhibited, in which the vertical and lateral pressures of the weight suspended were directed (by a combination of levers) to disengage the hooking parts which moved on eccentric bearings.

In the boats accumulated strength was given (to all the parts liable to alter) with the utmost compactness; and with all the detailed requirements these boats of the same size packed together indiscriminately.

District Private Telegraphs. By NATH. J. HOLMES.

The introduction and use of private telegraphs in this country is of comparatively recent date. The apparatus in use upon the railways in signalling trains, and by the telegraph companies for the transmission of public messages, is unsuitable for the requirements of the private telegraph. The employment of conventional signs, and what is technically known as the "dot and dash" system, renders the signals unintelligible except in the hands of properly trained clerks. In 1840 Prof. Wheatstone patented his first alphabetical telegraph.

This instrument has since been greatly improved, and another patent was taken out in 1858, from which year the general introduction of private telegraphs may be dated. The first private lines erected in London under the new system were those of Messrs. Spottiswoode, Messrs. Waterlow and Son, and the London Dock Company.

In the year 1860 Prof. Wheatstone and Mr. Nath. J. Holmes established the present Universal Private Telegraph Company for the purpose of providing private wires in various parts of the kingdom upon a system of annual rentals. This Company, afterwards incorporated in 1861, has already extended its system to every important town and district in the kingdom, and during the last four years has erected upwards of 2000 miles of private wire, employing 863 sets of instruments.

On the Applicability of India-rubber as an Insulator for Telegraphic Conductors. By W. HOOPER.

The author noticed the difficulties encountered in applying caoutchouc for insulating purposes, describing the decay of caoutchouc, especially when exposed to air and light, arising from oxidation, and resulting in a condition of fluidity. In applying caoutchouc as an insulator, it has been generally washed, dried, and masticated, being manufactured by the process into solid blocks, which are then cut up into

sheets, which are again divided into tapes. After the tapes have been wound round the wires, they have usually been consolidated by heat, or by the use of solvents, both of which are injurious by their tendency to favour oxidation. Wires thus insulated give good results for a short time, but their efficiency is soon destroyed. The results obtained with five specimens of india-rubber-covered wire supplied by different manufacturers for experimental purposes to the Government of India, and sent out to Kurrachee in 1863, were adduced by the author, and showed that four out of the five were defective after submersion in the Indian Ocean, the one only, supplied by himself, remaining perfect. In insulation this specimen was the highest yet attained, and the perfection of the joints was fully proved. The central position of the conductor was unaltered by any elevation of temperature, and its insulation remained good up to 150° Fahrenheit, and even higher temperatures. The mechanical properties of the core devised by the author, were also shown to surpass all other materials yet produced. The importance of the low inductive capacity of the wires, insulated by the author's process, was dwelt upon. Sir Chas. Bright, Mr. Latimer Clark, and Professor Thomson, had made independent investigations into the capabilities of the wire thus insulated, and the results deduced by those gentlemen were singularly in accordance with each other, the two former giving the induction of the author's wire compared with gutta percha as 100 to 136, the latter as 100 to 135. The rate of signalling being proportionate to the retardation arising from induction, the value of the process, in a line of such length as the Atlantic cable, would be at once apparent in a commercial as well as a scientific view. The Government have since ordered three lengths of 50, 40, and 45 miles of this insulated wire, which are now *en route* for India.

Machinery for compressing Air, and the Applicability of such Compressed Air for working Coal-cutting and other Underground Machinery. By T. LEVICK.

The advantages which the paper described were:—1. The simplicity of construction, and small cost. 2. The small amount of power to overcome the friction of the moving parts. 3. It was not affected by the production of heat in the compressed air. 4. It acted as a regulator, adapting its speed to the consumption of air underground. 5. Being used at the mouth of coal-pits, the additional loss of power was not of so much consequence. 6. The small amount of space occupied. The paper explained that the air compressed by the engine at the mouth of the pit was conveyed to the machinery underground in 4-inch cast-iron pipes, carried along the main-headings, from which the compressed air was conveyed in 1½-inch gas piping, connected with the machine in the pit by an india-rubber hose. The prominent feature of the machine is a pick, which digs the coal when the engine at the mouth of the pit is in motion. The pick can be worked at any angle at which the coal may lie, and can be easily put to work at any part of the thickness of the coal, whether it might be desired to "hole" in the bottom or at the top of the measure, or at a parting in the middle, or any other portion of it, by simply shifting the pick to a greater or less distance upon the axis on which it is keyed. The machine moves forward as the work progresses by means of a hand wheel, which communicates motion by bevel wheels to the wheels upon which the machine travels. In cases of bad roof, the use of the coal-cutting machines had been objected to on account of the distance required (between the face of the work and the supports to the roof) for the back work of the pick. Another objection was that the work had to be passed over twice or three times, in order to gain the required depth of cut. These objections have been obviated by the machines introduced to notice, by which the stroke of the pick, when making its cut, was from the back of the cut towards the face, instead of passing across the road and striking into the face in the direction observed heretofore. By this means the supports to the roof could be brought close up to the road; the concussion of the blow was reduced; and about six inches of the coal had not to be cut, it being forced out as the pick approached the face. The quantity of compressed air consumed by each coal-cutter was determined from some indicator diagrams to be 327·6 cubic feet per minute, at 30 lbs. pressure. The machine was working at 98 strokes

per minute, showing an expenditure of air equal to 3 horse-power. The machines at Blaia Ironworks, South Wales, were working in coal which the men refused to work, and which, though opened out, has not been touched for years, and hole at the rate of 8 yards per hour, to a depth of 3 feet. The machine, when worked with the outward cut and self-propelling motion, will exceed this quantity considerably.

On some Developments of and Improvements in Giffard's Injector.

By J. ROBINSON.

Having referred to the difference of opinion existing among engineers as to this, which had been called by the President a somewhat paradoxical instrument, the author described the action of the injector to be as follows:—Steam was taken from the steam space of any boiler by means of the injector, the water supply was brought into contact with the steam current, and the result in the shape of hot water was passed into the water space of the boiler. The question was, how, having an equal pressure on all parts of the boiler, did a fluid not only pass in the shape of a current from one part to another, but at the same time carry with it another fluid exposed to atmospheric pressure only? The author propounded the following explanation of the instrument:—Advantage is taken of the superior velocity at which a steam current issues from a boiler, over that of a water current issuing from a boiler at the same pressure. These velocities are assumed to bear an exact proportion to the densities of the two fluids. The steam current having but a small amount of momentum, the water supply is brought into contact with it, and two results follow: first, the steam current is incorporated with the water current by the condensation of the former; secondly, an amount of the velocity of the steam current is imparted to the water current in the proportion of the quantities of each which are brought together in the combined jet. As the weight of steam issuing from an opening is exactly equal to the weight of water which would, under the like pressure, issue from the same opening in the same time, the area for the admission of steam to the combining chamber is made greater than the area of the pipe which receives the condensed jet for transmission to the boiler, as otherwise the amount of velocity imparted to the water current would not be sufficient to overcome the velocity of the resisting current from the boiler. The combination of the foregoing principles and arrangements in the injector is so effective that, steam at a pressure of 30 lbs. above the atmosphere, water can be forced into a boiler containing steam of very nearly double that pressure. Having described the construction of the injector, the paper pointed out the importance of an apparatus capable of supplying water to steam boilers without motion of any of its parts, and independently of the engine connected with it. It had proved almost essential to some particular arrangements of boilers and engines. For locomotives, the advantage had been very considerable, inasmuch as it was most important that the machinery of engines running at such high velocity should be free from the apparatus and repairs necessary when their boilers were fed by pumps worked by the engine. The advantage also was obtained by feeding the boiler while the locomotive was at rest, either in the station, or during its retention in a siding waiting for the line to be cleared. For this purpose 5230 of the injectors had been manufactured in this country. For stationary boilers the injector had been found convenient, because of the saving of the pipes and other communication from the boiler to the engine-room, the suppression of the pumps and the parts of the engine necessary to work them, and the advantage of being able to fill up the boilers during meal hours, and at other times when the engine was stopped. For this purpose 3816 had been made in this country. For marine boilers the apparatus was most convenient, since it answered generally the purpose both of the main engine pumps and of the donkey pumps, and brought the control of the feeding-apparatus within reach of the stokers, without reference to the engine-room, and without the noise and complication of the donkey pump. In a simple form, and also in the ordinary injector arrangement, the principle had been applied for raising water from mines and wells, the inducement being the cheapness and simplicity of the apparatus, and the small space and easy manipulation required. The paper proceeded to describe in detail improvements which had

been made upon the injector as it first came from the hand of the inventor; but these cannot be made clear without a reference to diagrams.

On the Outer Covering of Deep-sea Cables. By C. W. SIEMENS, C.E.

The want of success which has hitherto attended deep-sea cables renders it perhaps desirable that the attention of the Section should be called to the subject. We are able at present to point to shallow sea-lines, such as the Dover and Calais, the Port Patrick and Dunagadee, and the Dover and Ostend lines, which have lasted above fourteen years, and in which the electric conductors, together with their insulating coating, remains to this day unimpaired, although the thick iron wires which constitute their outer covering are greatly diminished in strength through oxidation, and have given rise to occasional repairs. It has, moreover, been proved, beyond doubt, that the great hydrostatic pressure upon deep-sea cables does not deteriorate the insulated conductor, but, on the contrary, greatly improves the insulation; and, as regards the durability of the outer covering, deep-sea cables have the natural advantage over shallow sea-lines that they lie upon tranquil ground far beyond the reach of currents, of accidental disturbances through ship's anchors or the coral-fisher's hooks, and, to some extent at least, beyond the reach of animal life. The drawbacks to these advantages are, that the risk of accident is greater in laying down deep-sea lines, and that, when laid, they are less accessible for repairs; but these circumstances do not suffice to account for the very rapid failure of those deep-sea cables which had been successfully submerged, as, for instance, the first Atlantic, the Toulon and Algiers, and other lines in the Mediterranean.

But why, it may be asked, are deep-sea cables not made precisely the same as shallow sea- or shore-end lines, seeing that the latter have given proof of greater strength and durability? The answer is that the laying of a heavy iron-clad cable into deep seas would be attended with great risk, because the retarding force which has to be applied to a cable in going overboard increases with the depth (or length of suspended cable), and would amount to several tons; tug-steamers would have to be applied to assist the cable-ship, and any stoppage in the operation through the breakage and entanglement of a wire, or other cause, might seriously compromise the safety of the cable and of the ships themselves. Moreover, deep-sea cables are generally *long* cables, and ships could hardly be found to carry a heavy cable of the requisite length in one piece, nor could it be joined with safety on the open seas. The risk of breakage of a heavy deep-sea cable would also be great, because the thick iron wires composing the same could hardly reach down to the bottom of the North Atlantic without breaking by their own dead weight.

Considering these circumstances, it becomes evident that the strength and permanency of a deep-sea cable cannot be attained by thick iron wires, but that other materials and modes of construction must be had recourse to.

In reviewing past experience, we find that in the case of the Varna and Balaclava cable (300 miles), which was laid in 1858, no sheathing of any kind was applied to the insulated conductor. The operation of paying out was accomplished with great ease and success, and the electrical communication was kept open for nearly nine months, when it suddenly ceased, in consequence either of chafing against rocks or shells, or the tooth of the Tereido.

Several cables were laid in the Mediterranean in 1855 and 1856, consisting of an insulated conductor covered with strings of tarred hemp, which was laid on in the manner of an iron sheathing. A difficulty was experienced in laying this description of cable, owing to its excessive specific lightness and roughness of surface, which combined to make it sink so very slowly to the bottom, that it was paid out, as it were, in a straight line upon the surface of the water; and although no break-power whatever was applied, not sufficient cable would leave the ship to cover the irregularities of the bottom. This tightening of the cable, when laid, was further increased by the shrinkage of the hemp strings in the water, and, moreover, by the action of local currents in the water, to which the cable remained exposed for a long time during its descent. The consequence was that the cable strained and broke during the operation of laying, or rather immediately after. In raising this cable

a few months later, it was found, moreover, that the hemp had engendered millions of small marine insects of a peculiar kind (the *Xylophaga*, according to Huxley), which had not only completely destroyed the rope, but had eaten deep holes in the gutta percha without reaching, however, the copper conductor. This action had been accomplished at a depth of from 300 to 500 fathoms.

Several heavy iron-covered cables have been laid into moderately deep water in the Mediterranean, some of which were laid successfully, though at great risk, and with great loss of cable, and have worked for several years before giving way. The most remarkable is the Spezzia and Corsica cable, which consisted of six insulated conductors served with tarred hemp, and sheathed with twelve galvanized iron wires of $\frac{3}{16}$ ths of an inch diameter, producing a weight of $8\frac{1}{2}$ tons per mile of cable. This cable was laid in 1854 in a depth of 600 fathoms, and remained in good working order till 1863, when it failed.

The Red Sea and Indian cable was laid successfully in 1859–60, but failed after nine months' exposure to the sea-water, when it was found that the iron sheathing, consisting of sixteen wires, and weighing 2 tons per mile, had been completely corroded through in places.

The first Atlantic cable, which was laid in 1857, had a sheathing of a peculiar form, consisting of 126 thin charcoal iron wires of No. 22 $\frac{1}{2}$ B.W.G., giving it great relative strength during the process of laying. Considering, however, the large exposure of iron surface to corrosive action of the sea, this cable must have failed a few weeks after submersion, if the insulated conductor had not been so defective in itself as to render the cable unfit for regular telegraphic communication from the first.

Another type of sheathing for a deep-sea cable is that which was adapted for the Toulon and Algiers line in 1860; it consisted of ten steel wires, each of which had been previously covered with tarred hemp, for the purpose of giving it additional strength and protection against corrosion by sea-water. It was proved by experiments that the strength of each steel wire was increased to the full amount of the strength of the hemp serving, or about 20 per cent., while at the same time the specific gravity of the cable was greatly decreased, and its descent through the water further retarded, in consequence of the rough surface the hemp serving presents. The insulated conductor of this cable was well proportioned and carefully tested, and its sheathing was found to be such that a moderate break-power sufficed to prevent its running out too fast in the laying, while at the same time the cable descended with sufficient rapidity to provide the necessary slack (about 10 per cent.). Thus far this compound sheathing of steel and hemp had proved a complete success, when about six months after its submersion the continuity suddenly ceased, and in endeavouring to raise the cable it was found that the marine insects (*Xylophaga*) had again done the work of destruction, having completely eaten the hemp and left the steel wires like a loose cage around the insulated conductor, and fully exposed to corrosive action.

These repeated failures of the outer covering of deep-sea cables led the writer to devise one which combines the requisites of low specific gravity and relative strength with greater durability than could hitherto be attained. A cable of this description actually forms an important link in the telegraphic chain which now unites France with its African dependency, and is therefore practically entitled to consideration. It consists of the ordinary insulated copper conductor, which is covered in one process with two layers of best Italian hemp moderately twisted in opposite directions, and lastly with an outer binding sheathing of copper, which is put on under great pressure, and in such a manner that the copper strips composing the same overlap, and are, as it were, mortised into one another, producing practically the effect of a complete flexible tube. Each string of hemp is put on in the machine under an equal strain, which gives to the rope a strength fully equal to the sum of all its constituents. The metal of the outer sheathing is copper mixed with about $\frac{1}{4}$ per cent. of phosphorus, which imparts to it greater tenacity, and an increased power to resist chemical action in the sea-water. Instead of copper, zinc has sometimes been used, which also resists sea-water in a remarkable degree.

The hemp gives great relative strength to this cable. The Algeria cable, with an outer diameter of only $\frac{1}{2}$ inch, bears a strain exceeding $1\frac{1}{2}$ ton; and a cable of

the dimensions proposed by the writer for the Atlantic, having a diameter of $\frac{3}{4}$ inch, bears between 3 and 4 tons of longitudinal strain before breaking, or fully as much as an iron-covered cable of the same diameter, while its weight in sea-water is from five to six times less.

The machine used in the manufacture of this cable presents several practical mechanical combinations, which the writer, however, passed over, in order not to extend the subject of this paper.

The peculiar properties of this cable, as contrasting with the ordinary cable with helical or spiral sheathing, are as follows:—

1st. The absolute strength of this cable can be increased to any desired extent without adding to its weight in water, the hemp being very nearly of the same specific gravity as the water itself. Considering past experience, a specific gravity of $1\frac{1}{2}$, and a strength sufficient to support from ten to twelve miles of weight of the cable in sea-water appears desirable.

2ndly. The elongation of this cable under half its breaking strain does not exceed $\frac{1}{2}$ per cent., and has no tendency to untwist when suspended from one end, whereas an iron-sheathed cable (or a cable of the Toulon and Algiers type) will elongate from 3 to 4 per cent. under similar circumstances, and partially untwist at the same time, because each wire tends to assume a straight line parallel to the axis. This elongation throws a great and dangerous strain upon the insulated conductor, which will be permanently elongated and disposed to fall into kinks at the bottom.

3rdly. In the manufacture of iron-clad cables the insulated conductor frequently gets injured through the breakage of a wire, or the carelessness of workmen in making welds, and the cable, when manufactured and in the very act of being paid overboard, may be penetrated by the sharp end of a broken wire, as has most unfortunately happened on a recent occasion. The copper-sheathed cable precludes almost the possibility of any such accidental injury; the insulated conductor, after being carefully tested, passes through the sheathing-machine, where it receives spontaneously its double hemp covering and complete metallic armour coat. It is worthy of remark that the insulation resistance of the cores invariably increases in receiving the armour coat, owing, it appears, to the external pressure produced, and that not a single, fault of insulation has ever occurred in the cable during the processes of shipment and submersion.

4thly. The durability of the copper-sheathed cable has already been proved by experiment and in actual practice. A cable which had been laid in 1864 in the Mediterranean, from Oran to Carthage, was raised again nine months later (in consequence of an accident of a purely mechanical nature) from a depth of 1500 fathoms, when it was found to be in a perfectly good condition, the insulation and the strength of the hemp being unimpaired, and the copper sheathing being covered by a thin green scale of chloride of copper and magnesia, it is supposed, which appears to have arrested further chemical action. The cable so recovered, and of which a specimen was exhibited, now forms part of the line connecting Sicily with Algeria; whereas the iron-sheathed shore-end cable, which was also recovered, was found to be unfit for further use, being much corroded and covered with coral growth.

5thly. The copper-sheathed cable is mechanically well suited to the operations of laying; it is extremely flexible, occupies relatively little space in the ship's hold, and glides smoothly overboard without the least risk of catching by broken wires, or of forming into kinks, or untwisting under strain. It offers remarkably little resistance in the water, and can be recovered from the greatest depth at the rate of one knot per hour.

It has been objected that hemp rope contracts very considerably (about 3 per cent.) upon being immersed, and that the copper-sheathed cable must be liable to the same injurious effect. While fully admitting the general proposition, the writer has no difficulty to show that it does not apply to the cable in question.

It was seen from the experiment which was shown to the Section, that although a twisted hemp rope contracts upon being moistened, a single hemp fibre, taken from the same rope, actually elongates under the same treatment, the reason

being, as it appears to the writer, that each hemp fibre consists of a series of collapsed tubes between knots, which, upon filling with water, straighten from knot to knot, and therefore slightly augment the total length; whereas the same fibre, if wound spirally, will reduce the length of the spiral, in consequence of its increase in diameter in filling with water. Proceeding from this consideration, hemp yarn of little twist is used in the manufacture of this cable, the copper sheathing binding the fibres sufficiently to continue their strength, and the result is that its length remains practically the same upon being immersed.

In drawing this paper to a conclusion, the writer feels that he has laid himself open to the charge of partiality in favour of one particular covering, but his excuse is that he could not have done otherwise without doing violence to his convictions, which, however, are open to criticism. So much will, he thinks, be readily conceded, that the failure of deep-sea cables has hitherto been mainly due to the mechanical imperfections and perishable nature of the outer coverings. The unfortunate result of the last attempt to establish telegraphic communication with America goes to strengthen this proposition. Both the insulated conductor and the paying-out machinery had been prepared with extreme care; the great ship was well adapted to its important work, which in all human probability would have been crowned by success but for the unfortunate injuries which the insulated core received through insufficient protection. The recurrence of the same kind of accident may perhaps be avoided by special care; but there remain the dangers of kinks at the bottom, through the untwisting of the rope while in suspension, and, most of all, the question of durability to be disposed of.

It has been maintained by some that the outer covering of deep-sea cables is only of use for submerging the same, and that its decay at the tranquil bottom of the ocean could not harm the insulation; but such a proposition is disposed of by experience, and it is natural to suppose that the sheathing must give way first in such places where it rests upon a stone or gentle elevation of the ground (and is most exposed to chemical action). Upon giving way, the cable will sink to take new bearings and cause the unsupported insulated conductor to separate. It may, on the other hand, be maintained that a permanent metallic sheathing is requisite to ensure the success of deep-sea as well as shallow-sea cables.

Description of a Patent Steam Pile-Driver. By W. Sissons.

In this machine the ram (one ton in weight) falls twelve times in a minute, with a 5-feet lift. The size of the bottom frame is only 7 feet 6 inches square, and it occupies a smaller space than an ordinary hand-machine, and can be used in any situation, on land or afloat, where the other can. It supplies a deficiency long felt, viz. something more powerful and expeditious than hand-machines, and something less ponderous and costly than those steam-machines hitherto brought out. During the past six years fifty-four of them have been made; seven are in use on the Thames Embankment, and Mr. Brassey has five in operation in Galicia.

*On Warming, Lighting, and Ventilating the Birmingham Town Hall.
By B. SMITH.*

List of Papers of which Abstracts have not been received.

On Arseniuretted and Antimoniuretted Hydrogens. By W. L. SCOTT.

On the Formation of Ammonia from Nitrogen in the Atmosphere.
By W. L. SCOTT.

On the Presence and Functions of Ammonia or its Homologues in the Blood.
By W. L. SCOTT.

On the Esquimaux. By Dr. RAE.

On Pericardial Fluid. By Dr. M. FOSTER.

On some New Expeditions in the Chain of Mont Blanc, including the Ascent of the Aiguille Verte. By E. WHYMPER.

On the Ascent of Mont Blanc by the Glacier de Brenva. By G. S. MATTHEWS.

On the Anthropoid and Mute Origin of the European Races, versus the Theory of Migration from an External Source. By the REV. DUNBAR J. HEATH, M.A.

Reports on Local Industries.

Description of a Rotary Steam-Engine. By W. R. THOMSON.

On the Ventilation of Separate Rooms, and of Large Assemblies and Coal Mines. By CORNELIUS VARLEY.

On an Atmospheric Hammer. By W. D. GRIMSHAW.

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PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at 18s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54;—Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

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$$\sum_0^t \frac{-\alpha a^{t+1} + \beta t^{t+1} + \delta t^{t+1}}{1^{t+1} \gamma^{t+1} \epsilon^{t+1}}, \alpha \text{ étant entier négatif, et de quelques cas dans lesquels cette somme}$$

est exprimable par une combinaison de factorielles, la notation a^{t+1} désignant le produit des t facteurs $a(a+1)(a+2) \&c \dots (a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel ;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth ;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ ;—John P. Hodges, M.D., on Flax ;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain ;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57 ;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains ;—Professor W. A. Miller, M.D., on Electro-Chemistry ;—John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude $71^\circ 21' N.$, long. $156^\circ 17' W.$, in 1852–54 ;—Charles James Hargreave, LL.D., on the Algebraic Couple ; and on the Equivalents of Indeterminate Expressions ;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings ;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester ;—William Fairbairn on the Resistance of Tubes to Collapse ;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee ;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load ;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature ;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive) ;—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

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the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

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Sir W. G. Armstrong, C.B., LL.D.
Sir Charles Lyell, Bart., M.A.,
LL.D.

GENERAL SECRETARY.

FRANCIS GALTON, Esq., M.A., F.R.S., F.R.G.S., 42 Rutland Gate, Knightsbridge, London.

ASSISTANT GENERAL SECRETARY.

GEORGE GRIFFITH, Esq., M.A., 5 Park Villas, Oxford.

GENERAL TREASURER.

WILLIAM SPOTTISWOODE, Esq., M.A., F.R.S., F.R.G.S., 50 Grosvenor Place, London, S.W.

AUDITORS.

James Heywood, Esq., F.R.S.

Robert Hutton, Esq., F.G.S.

Dr. Gladstone.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1866.

* indicates Life Members entitled to the Annual Report.

§ indicates Annual Subscribers entitled to the Annual Report.

† indicates Subscribers not entitled to the Annual Report.

Names without any mark before them are Life Members not entitled to the Annual Report.

Names of Members whose addresses are inaccurate or not known are in *italics*.

Notice of changes of Residence should be sent to the Assistant General Secretary.

Year of
Election.

- Abbatt, Richard, F.R.A.S. Marlborough-house, Woodberry Down, Stoke Newington, London.
1863. *Abel, Frederick Augustus, F.R.S., F.C.S., Director of the Chemical Establishment of the War Department, Royal Arsenal, Woolwich.
1856. †Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1863. *Abernethy, James. 2 Delahay-street, Westminster, London.
1860. §Abernethy, Robert, C.E. Ferry-hill, Aberdeen.
1854. †Abraham, John. 87 Bold-street, Liverpool.
- Acland, Henry W. D., M.A., M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
- Acland, Sir Thomas Dyke, Bart., M.A., D.C.L., F.R.S., F.G.S., F.R.G.S. Killerton, Devon.
1860. †Acland, Thomas Dyke, M.A., D.C.L., M.P. Sprydoncote, Exeter.
- Adair, John. 11 Mountjoy-square, Dublin.
- *Adair, Colonel Robert A. Shafte, F.R.S. 7 Audley-square, London.
- *Adams, John Couch, M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1856. †Addams, Robert.
- Adderley, The Right Hon. Charles Bowyer, M.P. Hams-hall, Coleshill, Warwickshire.
- Adelaide, Augustus Short, D.D., Bishop of. South Australia.
1860. *Adie, Patrick. 15 Argyle-road, Kensington, London.
1865. *Adkins, Henry. The Firs, Edgbaston, Birmingham.

Year of
Election.

1861. †Agnew, Thomas. Fair Hope, Eccles, near Manchester.
 1854. †Aikin, John. Princes Park, Liverpool.
 1845. †Ainslie, Rev. G., D.D., Master of Pembroke College. Pembroke Lodge, Cambridge.
 1864. *Ainsworth, David. The Floss, Egremont, Cumberland.
 Ainsworth, Peter. Smithills Hall, Bolton.
 1842. *Ainsworth, Thomas. The Floss, Egremont, Cumberland.
 1859. †Airlie, The Earl of. Airlie Castle, Forfarshire.
 1859. §Airston, Dr. William Baird. 4 Abbotsford-crescent, St. Andrew's, Fife.
 Airy, George Biddell, M.A., D.C.L., F.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich.
 1851. †Airy, Rev. William, M.A. Keysoe, Bedfordshire.
 1855. †Aitkin, John, M.D. 21 Blythswood-square, Glasgow.
 1842. *Aitkin, Thomas.*
 Akroyd, Edward. Bankfield, Halifax.
 1861. *Alcock, Ralph. 47 Nelson-street, Oxford-street, Manchester.
 1862. §Alcock, Sir Rutherford. The Athenæum Club, Pall Mall, London.
 1861. †Alcock, Thomas, M.D. 66 Upper Brook-street, Manchester.
 *Aldam, William. Frickley Hall, near Doncaster.
 Alderson, James, M.A., M.D., F.R.S. 17 Berkeley-square, London.
 1857. †Aldridge, John, M.D. 20 Ranelagh-road, Dublin.
 Alexander, James.
 1859. †Alexander, Colonel Sir James Edward, K.C.L.S., F.R.A.S., F.R.G.S. Westerton, Bridge of Allan, N. B.
 1851. †Alexander, R. D. St. Matthew's-street, Ipswich.
 1858. †Alexander, William, M.D. Halifax.
 1850. †*Alexander, William Lindsay, D.D.*
 1851. †Alexander, W. H. Bank-street, Ipswich.
 1863. §Allan, Miss. Bellevue House, Perth.
 1859. †Allan, Alexander. Scottish Central Railway, Perth.
 1862. §Allan, James, M.A., Ph.D. School of Practical Science, Sheffield.
 1850. †Allan, Robert. 29 York-street, Edinburgh.
 Allan, William. 22 Carlton-place, Glasgow.
 1846. †Allen, John Mead. Orchard-place, Southampton.
 1861. †Allen, Richard. Didsbury, near Manchester.
 Allen, William. 50 Henry-street, Dublin.
 1852. *Allen, William J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
 1863. §Allhusen, H. C. Elswick Hall, Newcastle-on-Tyne.
 *Allis, Thomas, F.L.S. Osbaldwick Hall, near York.
 *Allman, George J., M.D., F.R.S. L. & E., M.R.I.A., Regius Professor of Natural History in the University of Edinburgh. 21 Manor-place, Edinburgh.
 Allman, William, M.D.
 1844. *Ambler, Henry. Watkinson Hall, Ovenden, near Halifax.
 *Amery, John, F.S.A. Manor House, Eckington, Worcestershire.
 1855. †Anderson, Alexander D., M.D. 159 St. Vincent-street, Edinburgh.
 1855. †Anderson, Andrew. 2 Woodside-crescent, Glasgow.
 1850. †Anderson, Charles, M.D. 40 Quality-street, Leith.
 1850. †Anderson, Charles William. Cleadon, South Shields.
 1852. †Anderson, Sir James. Glasgow.
 1855. †Anderson, James. 46 Abbotsford-place, Glasgow.
 1855. †Anderson, James. Springfield Blantyre, Glasgow.
 Anderson, James A. Glasgow.
 1850. †Anderson, John. 31 St. Bernard's-crescent, Edinburgh.
 1850. †Anderson, John, D.D. Newburgh, Fifeshire.
 1859. §Anderson, Patrick. Dundee.

Year of
Election.

1850. †Anderson, Thomas, M.D., Professor of Chemistry, University of Glasgow.
1853. *Anderson, William (Yr.). Glentarkie, Strathmiglo, Fife.
1850. †Anderson, W., M.A. 1 Blacket-place, Edinburgh.
1861. †Andrew, *Jonah*.
*Andrews, Thomas, M.D., F.R.S., M.R.I.A., Vice-President of, and Professor of Chemistry in, Queen's College, Belfast.
1857. †Andrews, William. The Hill, Monkstown, Co. Dublin.
1859. †Angus, John. Town House, Aberdeen.
*Ansted, David Thomas, M.A., F.R.S., F.L.S., F.G.S., F.R.G.S., F.S.A. Athenæum Club; and Impington Hall, Cambridge.
1857. †Anster, John, LL.D. 5 Lower Gloucester-street, Dublin.
Anthony, John, M.D. Caius College, Cambridge.
Apjohn, James, M.D., F.R.S., M.R.I.A., Professor of Chemistry, Trinity College, Dublin. 32 Lower Bagot-street, Dublin.
1859. †Arbuthnot, *C. T.*
1850. †Arbuthnot, *Sir Robert Keith, Bart.*
1851. †Arcedeckne, Andrew. 1 Grosvenor-square, London.
1854. †Archer, *Francis*.
1855. *Archer, Professor T. C., F.R.S.E., Director of the Industrial Museum. 9 Argyll-place, Edinburgh.
1851. †Argyll, The Duke of, K.T., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London.
1865. §Armitage, J. W., M.D. 9 Huntriss-row, Scarborough.
1861. §Armitage, William. 7 Meal-street, Mosley-street, Manchester.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *Armstrong, Sir William George, C.B., LL.D., F.R.S. Elswick Works, Newcastle-upon-Tyne.
1856. †Armstrong, William Jones, M.A. Mount Irwin, Tynna, Co. Armagh.
Arnott, George A. Walker, LL.D., F.R.S.E., F.L.S., Professor of Botany in the University of Glasgow. Arlary, Kinross-shire.
Arnott, Neil, M.D., F.R.S., F.G.S. 2 Cumberland-terrace, Regent's Park, London.
1864. †Arrowsmith, John. Hereford-square, London.
1853. *Arthur, Rev. William, M.A. Glendun, East Acton, London.
Ashhurst, Thomas Henry, D.C.L. All Souls' College, Oxford.
1842. *Ashton, Thomas, M.D. 81 Mosley-street, Manchester.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
*Ashworth, Edmund. Egerton Hall, Turton, near Bolton.
Ashworth, Henry. Turton, near Bolton.
1845. †Ashworth, Rev. J. A. Dudcote, Abingdon.
1861. §Aspland, Alfred. Dukinfield, Ashton-under-Lyne, Lanrey, Windermere.
Aspland, Algernon Sydney. Saury, Windermere.
Aspland, Rev. R. Brook, M.A. 1 Frampton Villas, South Hackney, London.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. †Aston, Thomas. 4 Elm-court, Temple, London.
1858. †Atherton, Charles. Sandover, Isle of Wight.
1865. §Atkin, Alfred. Griffin's-hill, Birmingham.
1861. †Atkin, Eli. Newton Heath, Manchester.
1865. *Atkinson, Edmund, F.C.S. Royal Military College, Sandhurst, Farnborough.
1863. *Atkinson, G. Clayton. Wyland Hall, West Denton, Newcastle-on-Tyne.
1861. †Atkinson, *James*.
1845. †Atkinson *John*.
1858. *Atkinson, John Hastings. 14 East Parade, Leeds.

Year of
Election.

1842. *Atkinson, Joseph B. Stratford House, Carlisle-terrace, Kensington, W.
 1861. †Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
 1858. *Atkinson, J. R. W.
 Atkinson, William. Ashton Hayes, near Chester.
 1863. §Attfeld, Dr. J. 17 Bloomsbury-square, London.
 *Auldjo, John, F.G.S.
 1859. †Austin, Alfred.
 1860. *Austin, Rev. William E. C., M.A. Abbotstoke, Beaminster, Dorset.
 1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
 1865. *Avery, William Henry. Digbeth, Birmingham.
 1853. *Ayrton, W. S., F.S.A. Allerton-hill, Leeds.
 Babbage, B. H. 1 Dorset-street, Manchester-square, London.
 *Babbage, Charles, M.A., F.R.S. L. & E., Hon. M.R.I.A., F.R.A.S.
 1 Dorset-street, Manchester-square, London.
 *Babington, Charles Cardale, M.A., F.R.S., F.L.S., F.G.S., Professor
 of Botany in the University of Cambridge. (*Local Treasurer.*)
 St. John's College, Cambridge.
 Bache, Rev. Samuel. 44 Frederick-street, Edgbaston, near Bir-
 mingham.
 1845. †Back, Rear-Admiral Sir George, D.C.L., F.R.S., F.R.G.S. 109
 Gloucester-place, Portman-square.
 Backhouse, Edmund. Darlington.
 1863. †Backhouse, J. W. Sunderland.
 Backhouse, Thomas James. Sunderland.
 1851. †Bacon, George. Tavern-street, Ipswich.
 *Baddeley, Captain Frederick H., R.E.
 Bagot, Thomas N. Ballymoe, Co. Galway.
 1864. *Bailey, C. D. 7 Camden-crescent, Bath.
 Bailey, Samuel. Sheffield.
 1865. §Bailey, Samuel. The Peck, Walsall.
 1855. †Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
 1857. †Bailey, William Hellier, F.L.S., F.G.S., Acting Palæontologist to the
 Geological Survey of Ireland. 51 Stephen's Green, Dublin.
 *Bain, Richard. Gwennap, near Truro.
 1865. §Bain, Rev. W. J. Bilston.
 Bainbridge, Joseph. (Messrs. Morris and Prevost, Gresham House,
 London.)
 *Bainbridge, Robert Walton. Middleton House, near Barnard Castle,
 Durham.
 *Baines, Edward. Headingley Lodge, Leeds.
 1858. †Baines, Frederick. Burley, near Leeds.
 1858. *Baines, Samuel. Victoria Mills, Brighouse, Yorkshire.
 1865. §Baines, T.
 1858. †Baines, T. Blackburn. 'Mercury' Office, Leeds.
 1851. †Baird, A. W., M.D. Lower Brook-street, Ipswich.
 1846. †Baker, Rev. Franklin.
 1858. *Baker, Henry Granville. Bellevue, Horsforth, near Leeds.
 1865. §Baker, James P. Wolverhampton.
 1861. *Baker, John. Catley-hill, Cheadle, Cheshire.
 1861. *Baker, John. (R. Brooks & Co., St. Peter's Chambers, Cornhill,
 London.)
 1865. §Baker, Robert L. Victoria-villa, Moseley-road, Birmingham.
 1847. †Baker, Thomas B. Lloyd. Hardwick-court, Gloucester.
 1849. *Baker, William. 63 Gloucester-place, Hyde Park, London.
 1863. §Baker, William. 6 Taptonville, Sheffield.
 1845. †Bakewell, Frederick. 6 Haverstock-terrace, Hampstead.
 1860. §Balding, James, M.R.C.S. Barkway, Royston, Herts.

Year of
Election.

- Baldwin, Rev. John, M.A. Dalton, near Ulverston, Lancashire.
1851. *Baldwin, The Hon. Robert, H.M. Attorney-General. Spadina, Co. York, Upper Canada.
- *Balfour, John Hutton, M.D., M.A., F.R.S. L. & E., F.L.S., Professor of Medicine and Botany in the University of Edinburgh. 27 Inverleith-row, Edinburgh.
- *Ball, John, M.R.I.A., F.L.S. Oxford and Cambridge Club, Pall Mall, London.
1863. §Ball, Thomas. Bramcote, Nottingham.
- *Ball, William. Rydall, Ambleside, Westmoreland.
1852. †Bangor, Viscount. Castleward, Co. Down, Ireland.
1856. †Banks, Richard William. Kington, Herefordshire.
1846. †Banks, Rev. S. H., LL.D. Dullingham, Newmarket.
1842. *Bannerman, Alexander.*
1861. †Bannerman, James Alexander. Limefield House, Higher Broughton, near Manchester.
1853. †*Bannister, Anthony.*
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1859. †Barbour, George F. Bouskeid, Edinburgh.
- *Barbour, Robert. Portland-street, Manchester.
1855. †Barclay, Andrew. Kilmarnock, Scotland.
- Barclay, Charles, F.S.A., M.R.A.S. Bury-hill, Dorking.
- Barclay, James. Catrine, Ayrshire.
1852. *Barclay, J. Gurney. Walthamstow, Essex.
1860. *Barclay, Robert. Leyton, Essex.
1863. †Barford, J. Gale. Wellington College, Berks.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgeford, Nottinghamshire.
- Barker, James.*
1857. †Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. Dublin.
1865. §Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1846. †Barlow, Rev. John, M.A., F.R.S., F.L.S., F.G.S. 5 Berkeley-street, London.
- Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
- Barlow, Peter. 5 Great George-street, Dublin.
1857. †Barlow, Peter William, F.R.S., F.G.S. 26 Great George-street, Westminster, London.
1861. *Barnard, Major R. Cary. Cambridge House, Bays-hill, Cheltenham.
1864. *Barneby, John H. Brockhampton Park, Worcester.
- Barnes, Rev. Joseph Watkins, M.A., F.C.P.S. Kendal, Westmoreland.
- *Barnes, Thomas, M.D., F.R.S.E. Carlisle.
- Barnes, Thomas Addison. 9 Plough and Harrow-road, Edgbaston.
- *Barnett, Richard, M.R.C.S. 16 The Crescent, Oxford.
1859. †Barr, Lieut.-Colonel, Bombay Army. (Messrs. Forbes, Forbes & Co., 9 King William-street, London.)
1861. *Barr, W. R. Norris Bank, Heaton Norris, Stockport.
1860. †Barrett, T. B. High-street, Welshpool, Montgomery.
1852. §Barrington, Edward. Fassaroé Bray, Co. Wicklow.
1852. †Barrington, Richard S. Trafalgar-terrace, Monkstown, Co. Dublin.
1858. †*Barry, Rev. A.*
1862. *Barry, Charles. Lapswood, Sydenham-hill, Kent.
- Barstow, Thomas. Garrow-hill, near York.
1858. *Bartholomew, Charles. Broxholme, Doncaster.
1855. †Bartholomew, Hugh. New Gas-works, Glasgow.
1858. *Bartholomew, William Hamond. 5 Grove-terrace, Leeds.
1851. †Bartlet, A. H. Lower Brook-street, Ipswich.
1857. †Barton, Folloit W. Clonelly, Co. Fermanagh.

Year of
Election.

1852. †Barton, James. Newry, near Belfast.
 *Barton, John. Bank of Ireland, Dublin.
1864. §Bartrum, John S. 41 Gay-street, Bath.
1858. *Barwick, John Marshall. Albion-street, Leeds.
 *Bashforth, Rev. Francis, B.D. Minting, near Horncastle, Lincolnshire.
1861. †Bass, John H., F.G.S. 287 Camden-road, London.
1850. †Bastard, Thomas H. Charleton, Blandford.
1848. †Bate, C. Spence, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
 Bateman, James, M.A., F.R.S., F.L.S., F.H.S. Knypersley Hall,
 near Congleton, Staffordshire.
1842. *Bateman, John Frederic, C.E., F.R.S., F.G.S. 16 Great George-
 street, Westminster, London.
 *Bateman, Joseph, LL.D., F.R.A.S. Walthamstow, London.
1864. §Bates, Henry Walter, Assist.-Sec. R.G.S. 15 Whitehall-pl., London.
 Bateson, John Glynn. Liverpool.
1852. †Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1863. *Bathurst, Rev. W. H. Lydney Park, Gloucestershire.
1863. §Bauerman, H. 22 Acre-lane, Brixton, London.
1861. †Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1858. †Baxter, Robert.
 *Bayldon, John. Horbury, near Wakefield.
1851. *Bayley, George. 2 Cowper's-court, Cornhill, London.
1854. †Baylis, C. O., M.D. 51 Hamilton-square, Birkenhead.
- *1855. †Bayly, Capt., R.E. 205 St. Vincent-street, Glasgow.
 Bayly, John. 1 Brunswick-terrace, Plymouth.
1842. Bazley, Thomas Sebastian, B.A. Agden Hall, Lymm, Warrington.
 Beal, Captain. Toronto, Upper Canada.
1860. *Beale, Lionel S., M.B., F.R.S., Professor of Physiology and of Gene-
 ral and Morbid Anatomy in King's College, London. 61 Gros-
 venor-street, London.
 Beale, Samuel.
 Beamish, Francis B. Cork.
 *Beamish, Richard, F.R.S. (*Local Treasurer.*) Brightstone, New-
 port, Isle of Wight.
 Bean, R. H.
1861. §Bean, William. Alfreton, Derbyshire.
 *Beatson, William. Rotherham.
1857. †Beattie, Joseph.
1855. *Beaufort, William Morris, F.R.G.S. India.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London.
1864. †Beck, Richard. Lister Works, Holloway, London.
1851. †Becker, Ernest, Ph.D. Buckingham Palace, London.
1864. §Becker, Miss L. E. 10 Grove-street, Ardwick, Manchester.
1865. §Beckett, Henry, F.G.S. Pennover, near Wolverhampton.
1858. *Beckett, William. Kirkstall Grange, Leeds.
1860. †Beckles, Samuel H., F.R.S., F.G.S. 9 Grand Parade, St. Leonard's-
 on-Sea.
1846. †Beddome, J., M.D. Romsey, Hants.
1854. †Bedford, James, Ph.D.
1858. †Bedford, James.
1850. †Begbie, James, M.D. 21 Alva-street, Edinburgh.
1846. §Beke, Charles T., Ph.D., F.S.A., F.R.G.S. Bekesbourne House,
 near Canterbury, Kent.
1865. *Belavenetz, I., Captain of the Russian Imperial Navy, F.R.I.G.S.,
 M.S.C.M.A., Superintendent of the Compass Observatory,
 Cronstadt. (Care of Messrs. Baring Brothers, Bishopsgate-
 street, London.)

Year of
Election.

1847. *Belcher, Rear-Admiral Sir Edward, R.N., F.R.A.S., F.R.G.S. 22A
Connaught-square, Edgeware-road, London.
1847. †Belcher, William. Abingdon.
1850. †Bell, Charles, M.D. 3 St. Colme-street, Edinburgh.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. †Bell, George. Windsor-buildings, Dumbarton.
1860. †Bell, Rev. George Charles, M.A. The College, Dulwich.
1855. †Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1862. *Bell, Isaac Lowthian. The Hall, Washington, Co. Durham.
1853. †Bell, John Pearson, M.D. Waverley House, Hull.
*Bell, Matthew P. 245 St. Vincent-street, Glasgow.
1859. †Bell, Robert, jun. 3 Airlie-place, Dundee.
1864. †Bell, R. Queen's College, Kingston, Canada.
1855. †Bell, the late Sheriff. Glasgow.
Bell, Thomas, F.R.S., F.L.S., F.G.S., Professor of Zoology, King's
College, London. The Wakes, Selborne, near Alton, Hants.
1863. *Bell, Thomas. Usworth House, Gateshead, Durham.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1854. †Bellhouse, William Dawson. 1 Park-street, Leeds.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1864. *Bendyshe, T. 88 Cambridge-street, Pimlico, London.
1848. †Benham, E. 18 Essex-street, Strand, London.
1850. †Bennett, J. Hughes, M.D., F.R.S.E., Professor of Institutes of Medi-
cine in the University of Edinburgh. 1 Glenfinlas-street, Edin-
burgh.
1852. *Bennoch, Francis. The Knoll, Blackheath, Kent.
1857. †Benson, Charles. 11 Fitzwilliam-square West, Dublin.
Benson, Robert, jun. Fairfield, Manchester.
1848. †Benson, Starling, F.G.S. Gloucester-place, Swansea.
1863. §Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. †Bentham, George, F.R.S., Pres. L.S. 26 Wilton-place, Knightsbridge,
London.
1842. Bentley, John. 9 Portland-place, London.
1845. †Bentley, J. Flowers. Stamford, Lincolnshire.
1863. §Bentley, Robert, F.L.S., Professor of Botany in King's College. 55
Clifton-road, St. John's-wood, London.
1865. §Berger, C. H., F.C.S. Lower Clapton, London.
1863. †Berkley, C. Marley Hill, Gateshead, Durham.
Bermingham, Thomas.
1848. †Berrington, Arthur V. D. Woodlands Castle, near Swansea.
*Berryman, William Richard. 6 Tamar-terrace, Stoke, Devonport.
1862. †Besant, William Henry, M.A. St. John's College, Cambridge.
1865. §Bessemer, Henry. Denmark-hill, Camberwell, London.
1858. †Best, William. Leydon-terrace, Leeds.
1865. §Bevan, Hugh J. C. The Temple, London.
1859. †Beveridge, Robert, M.B. 20 Union-street, Aberdeen.
1863. †Bewick, Thomas John. Allenheads, Carlisle.
1857. †Bewley, Charles. Cope-street, Dublin.
*Bickerdike, Rev. John, M.A. St. Mary's Parsonage, Leeds.
Bickersteth, Robert. Rodney-street, Liverpool.
1863. †Bigger, Benjamin. Gateshead, Durham.
1864. §Biggs, Robert. 17 Charles-street, Bath.
1855. †Billings, Robert William. 4 St. Mary's-road, Canonbury, London.
Bilton, Rev. William, M.A., F.G.S. University Club, Suffolk-street,
London; and Chislehurst, Kent.
1842. Binney, Edward William, F.R.S., F.G.S. 40 Cross-street, Man-
chester.
1842. *Binyon, Thomas. Henwick Grove, Worcester.

Year of
Election.

- * Birchall, Edwin. 10 Chester-street, Bradford.
Birchall, Henry.
1854. † Bird, William Smith. Dingle Priory, near Liverpool.
1865. § Birkenhead, Edward Hasketh, D.Sc., F.G.S., Master of the Wigan School of Mines. Wigan.
Birkenshaw, John Cass.
1862. § Birkin, Richard. Apsley Hall, Nottingham.
* Birks, Rev. Thomas Rawson. Kelshall Rectory, Royston.
1842. * Birley, Richard. Seedley, Pendleton, Manchester.
1861. † Birley, Thomas Thornely. Highfield, Heaton Mersey, Manchester.
1841. * Birt, William Radcliff, F.R.A.S. 42 Sewardstone-road West, Victoria Park, London.
1854. † Bishop, Rev. Francis.
Black, James, M.D., F.G.S., F.R.S.E. 2 George-square, Edinburgh.
1863. † Black, William. South Shields.
Blackburn, Bewicke.
Blackburne, Right Hon. Francis. 34 Merrion-square South, Dublin.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1859. † Blackie, John Stewart, Professor of Greek. Edinburgh.
1855. * Blackie, W. G., Ph.D., F.R.G.S. 10 Kew-terrace, Glasgow.
* Blackwall, John, F.L.S. Hendre House, near Llanrwst, Denbighshire.
1863. § Bladen, Charles. Jarrow Iron Company, Newcastle-on-Tyne.
1859. † Blaikie, Sir Thomas. Kingsseat, Aberdeen.
1863. § Blake, C. Carter, F.G.S. Anthropological Society, 4 St. Martin's-place, Trafalgar-square, London.
1849. * Blake, Henry Wollaston, M.A., F.R.S. 8 Devonshire-place, Portland-place, London.
1846. * Blake, William. South Petherton, Ilminster.
1865. § Blakeley, Captain. Blakeley Ordnance Company, Bear-lane, Southwark, London.
1860. † Blakely, Capt. A. T. 34 Montpellier-square, Knightsbridge, London.
1845. † Blakesley, Rev. J. W., B.D. Ware Vicarage, Hertfordshire.
1861. § Blakiston, Matthew. Mobberley, Knutsford.
* Blakiston, Peyton, M.D., F.R.S. St. Leonard's-on-Sea.
Blanchard, Lieut.-Col.
* Bland, Rev. Miles, D.D., F.R.S., F.S.A., F.R.A.S. 5 Royal-crescent, Ramsgate.
Blanshard, William. Redcar.
Blood, William B.
Blore, Edward, F.S.A. 4 Manchester-square, London.
1853. † Blundell, Henry J. P. Brunswick House, Beverley-road, Hull.
1859. † Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
Blunt, Henry. Shrewsbury.
1859. † Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1850. † Blyth, John, M.D., Professor of Chemistry in Queen's College, Cork.
1858. * Blythe, William. Holland Bank, Church, near Accrington.
Boase, C. W. Dundee.
1845. † Bodmer, Rodolphe. Newport, Monmouthshire.
1864. † Bogg, J. Louth, Lincolnshire.
1866. † Bogg, Thomas Wemyss. Louth, Lincolnshire.
1859. * Bohn, Henry G., F.R.G.S. York-street, Covent Garden, London.
* Boileau, Sir John Peter, Bart., F.R.S. 20 Upper Brook-street, London; and Ketteringham Hall, Norfolk.
1859. † Bolster, Rev. Prebendary John A. Cork.

Year of
Election.

- Bolton, R. L. Gambier-terrace, Liverpool.
1849. †Bolton, Thomas. Hyde House, near Stourbridge.
1863. §Bond, Francis T., M.D. Hartley Institution, Southampton.
Bond, Henry John Hayes, M.D. Cambridge.
- *Bond, Walter M. The Argory, Moy, Ireland.
- Bonomi, Ignatius. 36 Blandford-square, London.
- Bonomi, Joseph. Soane's Museum, 15 Lincoln's-Inn-fields, London.
1861. †Booth, James. Yorkshire-street, Rochdale.
1835. †Booth, Rev. James, LL.D., F.R.S., F.R.A.S. The Vicarage, Stone,
near Aylesbury.
1861. *Booth, John. Monton, near Manchester.
1861. *Booth, Councillor William. Dawson-street, Manchester.
Boothman, Thomas.
1861. *Borchardt, Dr. Louis. Bloomsbury, Oxford-road, Manchester.
1849. †Boreham, William W., F.R.A.S. Haverhill, Suffolk.
1863. †Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.
- *Bossey, Francis, M.D. 4 Broadwater-road, Worthing.
- Bosworth, Rev. Joseph, LL.D., F.R.S., F.S.A., M.R.I.A., Professor
of Anglo-Saxon in the University of Oxford. Oxford.
1859. †Bothwell, George B. 9 Bon Accord-square, Aberdeen.
1858. §Botterill, John. Burley, near Leeds.
- Bottomley, William. Forbreda, Belfast.
1850. †Bouch, Thomas, C.E. 1 South Hanover-street, Edinburgh.
- Bourne, Lieut.-Col. J. D. Heathfield, Liverpool.
1858. †Bousfield, Charles. Roundhay, near Leeds:
1846. *Bowerbank, James Scott, LL.D., F.R.S., F.R.A.S. 2 East Ascent,
St. Leonard's.
1856. *Bowlby, Miss F. E. 27 Lansdown-crescent, Cheltenham.
1863. †Bowman, R. Benson. Newcastle-on-Tyne.
- Bowman, William, F.R.S. 5 Clifford-street, London.
- †Bowring, Sir John, LL.D., F.R.S. Athenæum Club, Pall Mall,
London; and Claremont, Exeter.
1863. §Bowron, James. South Stockton-on-Tees.
1863. §Boyd, E. F. Moor House, Durham.
- Boyle, Alexander, M.R.I.A. 35 College Green, Dublin.
1865. †Boyle, Rev. G. D. Soho House, Handsworth, Birmingham.
- Brabant, R. H., M.D. Bath.
- Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, War-
wickshire.
1849. †Bracey, Charles. Birmingham.
1864. §Bradbury, Thomas. Longroyde, Brighouse.
Bradshaw, Rev. John.
1861. *Bradshaw, William. Mosley-street, Manchester.
1842. *Brady, Antonio. Maryland Point, Essex.
1857. *Brady, Cheyne, M.R.I.A. Willow Bank, De Vescei-terrace, Kings-
town, Co. Dublin.
- Brady, Daniel F., M.D. 14 North Frederick-street, Dublin.
1863. †Brady, George S. 22 Fawcett-street, Sunderland.
1862. §Brady, Henry Bowman, F.L.S., F.G.S. 40 Mosley-street, Newcastle-
on-Tyne.
1858. †Brae, Andrew Edmund. 29 Park-square, Leeds.
1864. §Braham, P. 35A Great George-street, Westminster.
Braid, James.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
- *Brakenridge, John. Wakefield.
1865. §Bramwell, F. J. 35A Great George-street, Westminster.
- Branker, Rev. Thomas, M.A. Limington, Somerset.
1850. †Brand, William, F.R.S.E. 5 Northumberland-street, Edinburgh.

Year of
Election.

1861. *Brandreth, Henry. Eton.
Brandreth, John Moss. Preston, Lancashire.
1852. †Brazier, James S. Marischal College and University of Aberdeen.
1857. †Brazill, Thomas. 12 Holles-street, Dublin.
1859. †Brebner, Alexander C. Audit Office, Somerset House, London.
1859. *Brebner, James. 20 Albyn-place, Aberdeen.
1860. †Brett, G. Salford.
1854. *Brett, John Watkins. 2 Hanover-square, London.
1854. †Brewin, Robert.
1865. §Brewin, William. Cirencester.
- †Brewster, Sir David, K.H., LL.D., D.C.L., F.R.S. L. & E., Hon. M.R.I.A., F.G.S., F.R.A.S., Vice-Chancellor of the University of Edinburgh. Edinburgh.
1859. †Brewster, Rev. Henry. Manse of Farnell.
- *Briggs, General John, F.R.S., M.R.A.S., F.G.S. 2 Tenterden-street, London.
1863. *Bright, Sir Charles Tilston, C.E., F.R.G.S., F.R.A.S. 12 Upper Hyde Park-gardens, and 1 Victoria-street, Westminster, London.
- Bright, John, M.P. Rochdale, Lancashire.
1863. †Brivit, Henri. Washington Chemical Works, Washington, Durham.
1842. Broadbent, Thomas. Marsden-square, Manchester.
1848. †Brock, G. B. Bryn Tyfi, Swansea.
1859. †Brodhurst, Bernard Edwin. 20 Grosvenor-street, Grosvenor-square, London.
1847. †Brodie, Sir Benjamin C., Bart., M.A., F.R.S., Professor of Chemistry in the University of Oxford. Cowley House, Oxford.
1834. †Brodie, Rev. James. Monimail, Fifeshire.
1865. §Brodie, Rev. Peter Bellenger, M.A., F.G.S. Rowington Vicarage, near Warwick.
1842. *Brogden, John.*
1853. †Bromby, J. H., M.A. The Charter House, Hull.
- Bromilow, Henry G.*
1842. Brook, William. Meltham, York.
- *Brooke, Charles, M.A., F.R.S. 16 Fitzroy-square, London.
1855. †Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. T. Bannerdown House, Batheaston, Bath.
1855. †Brooke, Peter William. Marsden House, Stockport, Cheshire.
1863. §Brooks, John C. Wallsend, Newcastle-on-Tyne.
- *Brooks, Samuel. King-street, Manchester.
1846. §Brooks, Thomas (Messrs. Butterworth and Brooks). Manchester.
- Brooks, William. Ordfall-hill, East Retford, Nottinghamshire.
1847. †Broome, C. E. Elmhurst, Batheaston, near Bath.
1863. *Brough, Lionel H., F.G.S., one of Her Majesty's Inspectors of Coal-Mines. Clifton, Bristol.
- *Broun, John Allan, F.R.S., Astronomer to His Highness the Rajah of Travancore.
- Brown, Alexander, M.A.*
1863. †Brown, Alexander Crum, F.R.S.E. Arthur Lodge, Dalkeith-road, Edinburgh.
- Brown, Charles Edward. Cambridge.
1855. †Brown, Colin. 3 Mansfield-place, Glasgow.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1858. †Brown, Alderman Henry. Bradford.
1865. §Brown, Edwin, F.G.S. Burton-upon-Trent.
- Brown, Hugh. Broadstone, Ayrshire.
- Brown, James.*

Year of
Election.

1858. †Brown, John. Barnsley.
 1863. §Brown, John H. 29 Sandhill, Newcastle-on-Tyne.
 1863. †Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
 1856. *Brown, Samuel, F.S.S. The Elms, Larkhall Rise, Clapham, London.
 *Brown, Thomas. Hardwick House, Chepstow.
 *Brown, William. 3 Maitland Park Villas, Haverstock-hill, London.
 1855. †Brown, William. 179 Bath-street, Glasgow.
 1850. †Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
 1865. §Browne, William. The Friary, Lichfield.
 1865. §Brown, William. 41 a New-street, Birmingham.
 1863. †Browne, B. Chapman. Tynemouth.
 1854. †Browne, Henry, M.D.
 1862. *Brownne, Robert Clayton, B.A. Brownne's Hill, Carlow, Ireland.
 Browne, William. Richmond-hill, near Liverpool.
 1865. §Browning, John. 111 Minories, London.
 1855. †Brownlee, James. 173 St. George's-road, Glasgow.
 Brownlie, Archibald. Glasgow.
 1853. †Brownlow, William B. Villa-place, Hull.
 *Bruce, Alexander John. Kilmarnock.
 1852. †Bruce, Rev. William. Belfast.
 1851. †Bruff, P. Handford Lodge, Ipswich.
 1863. *Brunel, H. M. Duke-street, Westminster, London.
 1863. †Brunel, J. Duke-street, Westminster, London.
 1859. †Bryant, Arthur C.
 1858. †Bryant, Wilberforce.
 1861. §Bryce, James. 76 Oldham-street, Manchester.
 Bryce, James, M.A., LL.D., F.G.S. High School, Glasgow.
 Bryce, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
 1850. †Bryson, Alexander, F.R.S.E. Hawkhill, Edinburgh.
 1859. †Bryson, William Gillespie. Cullen, Aberdeen.
 Buchanan, Andrew, M.D., Regius Professor of the Institutes of
 Medicine in the University of Glasgow. Glasgow.
 Buchanan, Archibald. Catrine, Ayrshire.
 Buchanan, D. C. Poulton cum Seacombe, Cheshire.
 1850. †Buchanan George.
 Buchanan, James, R.E.
 *Buck, George Watson. Ramsay, Isle of Man.
 1864. §Buckle, Rev. George, M.A. Twerton Vicarage, Bath.
 1846. †Buckley, Colonel. New Hall, Salisbury.
 1865. *Buckley, Henry. Church-road, Edgbaston. Birmingham.
 1847. †Buckley, Rev. W. E., M.A. Middleton Cheney, Banbury.
 1848. *Buckman, James, F.L.S., F.G.S., Professor of Natural History in the
 Royal Agricultural College, Cirencester. Bradford Abbas, Sher-
 bourne, Dorsetshire.
 1851. *Buckton, G. Bowdler, F.R.S. Weycombe, Haslemere, Surrey.
 1848. †Budd, Edward. Hafod Works, Swansea.
 1848. *Budd, James Palmer. Ystalyfera Iron Works, Swansea.
 1851. †Bullen, George. Carr-street, Ipswich.
 *Buller, Sir Antony. Pound, near Tavistock, Devon.
 1845. †Bunbury, Sir Charles James Fox, Bart., F.R.S., F.L.S., F.G.S.,
 F.R.G.S. Barton Hall, Bury St. Edmunds.
 1845. †Bunbury, Edward H., F.G.S. 15 Jermyn-street, London.
 Bunch, Rev. Robert James, B.D., F.C.P.S. Emanuel Rectory,
 Loughborough.
 1863. §Bunning, T. Wood. 34 Grey-street, Newcastle-on-Tyne.
 Bunt, Thomas G. Nugent-place, Bristol.
 1854. †Burckhardt, Otte. Bank Chambers, Liverpool.
 1842. Burd, John.

Year of
Election.

1842. **Burd, John, jun.*
 1863. *Burgess, John. Rastrick, Yorkshire.
 Burgoyne, General Sir John F., Bart., G.C.B., D.C.L., F.R.S., In-
 specter General of Fortifications. 8 Gloucester-gardens, London.
 1857. †Burk, J. Lardner, LL.D. 2 North Great George-street, Dublin.
 1865. §Burke, Luke. 5 Albert-terrace, Acton, London.
 Burn, William.
 1859. †Burnett, Newell. Belmont-street, Aberdeen.
 1860. †Burrows, Montague, M.A., Commander R.N. Oxford.
 1857. †Busby, John. 9 Trafalgar-terrace, Monkstown, Ireland.
 1864. †Bush, W. 7 Circus, Bath.
 Bushell, Christopher. Royal Assurance-buildings, Liverpool.
 1855. *Busk, George, F.R.S., Sec. L.S., F.G.S., Examiner in Comparative
 Anatomy in the University of London. 15 Harley-street, Caven-
 dish-square, London.
 1857. †Butcher, Rev. S., D.D. 13 Fitzwilliam-square West, Dublin.
 Butler, Spilsbury.
 1857. †Butt, Isaac.
 Butterfield, Rev. Charles Dales. West Retford Rectory, West
 Retford.
 1845. †Butterfield, J. M. 45 Mount, York.
 1861. *Butterworth, John. 58 Mosley-street, Manchester.
 1855. *Buttery, Alexander W. Monkland Iron and Steel Company, Cardar-
 roch, near Airdrie.
 1845. †Button, Charles.
 Buxton, Edward North.
 1854. †Byerley, Isaac. Seacombe, Liverpool.
 Byng, William Bateman. Orwell Works House, Ipswich.
 1852. †Byrne, Rev. Jas. Ergenagh Rectory, Omagh, Armagh.

 Cabbell, Benjamin Bond, M.A., F.R.S., F.S.A., F.R.G.S. 1 Brick-
 court, Temple; and 52 Portland-place, London.
 Cabbell, George.
 1854. †Cadell, William. Monteith.
 1858. §Cail, John. Stokesley, Yorkshire.
 1863. †Cail, Richard. The Fell, Gateshead.
 1854. †Caine, Nathaniel. Dutton-street, Liverpool.
 1858. *Caine, Rev. William, M.A. Greenheys, Manchester.
 1863. †Caird, Edward. Finnart, Dumbartonshire.
 1861. *Caird, James Key. Finnart on Loch Long, by Gare Loch Head,
 Dumbartonshire.
 1855. *Caird, James T. Greenock.
 1857. †Cairnes, Prof. Queen's College, Galway.
 1845. †Calder, Rev. William. Fairfield Parsonage, Liverpool.
 Caldwell, Robert. 9 Bachelor's-walk, Dublin.
 1857. †Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth
 College.
 1842. Callender, W. R. The Elms, Didsbury, Manchester.
 1853. †Calver, E. K., R.N. 21 Norfolk-street, Sunderland.
 1857. †Cameron, Charles A., M.D. 17 Ely-place, Dublin.
 Cameron, John. Glasgow.
 1859. †Campbell, Rev. C. P., Principal of King's College, Aberdeen. Aber-
 deen.
 1857. *Campbell, Dugald, F.G.S. 7 Quality-court, Chancery-lane, Lon-
 don.
 1855. †Campbell, Dugald, M.D. 186 Sauchiehall-street, Glasgow.
 Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square,
 London; and Marchmont House, near Dunse, Berwickshire.

Year of
Election.

- *Campbell, Sir James. Glasgow.
Campbell, Rev. James, D.D. Forkhill, Dundalk, Ireland.
1855. †*Campbell, John.*
Campbell, John Archibald, F.R.S.E. Albyn-place, Edinburgh.
1852. †Campbell, William. Donegal-square West, Belfast.
1859. †Campbell, William. Dunmore, Argyllshire.
1862. *Campion, Rev. William. Queen's College, Cambridge.
1853. †Camps, William, M.D., F.L.S., F.R.G.S. 40 Park-street, Grosvenor-square, London.
Cape, Rev. Joseph, M.A., F.C.P.S. Birdbrook Rectory, Halstead, Essex.
- *Carew, William Henry Pole. Antony House, near Devonport.
1861. †Carlton, James. Mosley-street, Manchester.
Carmichael, H. 18 Hume-street, Dublin.
Carmichael, James.
Carmichael, John T. C. Messrs. Todd & Co., Cork.
- *Carpenter, Philip Pearsall, B.A., Ph.D. Montreal, Canada.
1854. †Carpenter, Rev. R. Lant, B.A. Halifax.
1845. †Carpenter, William B., M.D., F.R.S., F.L.S., F.G.S., Registrar of the University of London. 56 Regent's Park Road, London.
Carpmael, William. 24 Southampton-buildings, Chancery-lane.
1856. †Carr, John. Queen's Circus, Cheltenham.
1849. †Carr, William. Gomersal, Leeds.
1842. *Carr, William, M.D., F.R.C.S. Lee Grove, Blackheath, Kent.
1855. †*Carrick, John.*
1861. *Carrick, Thomas. 37 Princess-street, Manchester.
1861. *Carson, Rev. Joseph, D.D., Fellow of Trinity College, Dublin, M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. †Carte, Alexander, M.D. Royal Dublin Society, Dublin.
1845. †Carter, G. B. Lord-street, Liverpool.
1845. †*Carter, James.*
1855. †Carter, Richard, C.E. Long Carr, Barnsley, Yorkshire.
*Cartmell, Rev. James, D.D., F.G.S., Master of Christ's Coll. Cambridge.
Cartmell, Joseph, M.D. Carlisle.
Cartwright, Rev. R. B.
1862. †Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1842. *Cassels, Rev. Andrew, M.A. Batley Vicarage, near Leeds.
Castle, Charles. Clifton, Bristol.
Castle, Robert. Cleeve Court, Bristol.
1853. †Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1855. †*Catterill, Rev. Henry.*
1859. †Catto, Robert. 44 King-street, Aberdeen.
1849. †Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §Cayley, Arthur, F.R.S., V.P.R.A.S., Sadlerian Professor of Mathematics in the University of Cambridge. Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1858. *Chadwick, Charles, M.D. 35 Park-square, Leeds.
1860. §Chadwick, David. 64 Cross-street, Manchester.
1842. Chadwick, Edwin, C.B. Richmond, Surrey.
1842. Chadwick, Elias, M.A. Pudleston-court, near Leominster.
1842. Chadwick, John. Broadfield, Rochdale.
1859. †Chadwick, Robert. Highbank, Manchester.
1861. †Chadwick, Thomas. Wilmslow Grange, Cheshire.
- *Challis, Rev. James, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 13 Trumpington-street, Cambridge.

Year of
Election

1859. †Chalmers, John Inglis. Aldbar, Aberdeen.
 1859. †Chalmers, Rev. Dr. P. Dunfermline.
 1865. §Chamberlain, J. H. Christ Church-buildings, Birmingham.
 1842. Chambers, George. High Green, Sheffield.
 Chambers, John. Ridgefield, Manchester.
 *Chambers, Robert, F.R.S.E., F.L.S., F.G.S. 17 Hereford-square,
 Mayfair, London.
 1865. §Chambers, T. M. 38 Waterloo-road South, Wolverhampton.
 *Champney, Henry Nelson. St. Paul's-square, York.
 1865. §Chance, A. M. Edgbaston, Birmingham.
 1865. *Chance, James Simmers. Brown's Green, Handsworth, Birmingham.
 1865. §Chance, Robert Lucas. Chad Hill, Birmingham.
 1861. *Chapman, Edward. Frewen Hall, Oxford.
 1850. †Chapman, Prof. E. J. University College; and 4 Addison-terrace,
 Kensington, London.
 1861. *Chapman, John. Hill End, Mottram, Manchester.
 Chapman, Captain John James, R.A., F.R.G.S. Adelaide-square,
 Bedford.
 1854. †Chapple, Frederick. Canning-street, Liverpool.
 Charlesworth, Edward, F.G.S. Whittington Club, Arundel-street,
 London.
 1863. †Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
 1863. †Charlton, F. Braithwaite, Cockermouth.
 Chatto, W. J. P. Union Club, Trafalgar-square, London.
 1864. †Cheadle, Dr. 8 Old Cavendish-street, London.
 1842. *Cheetham, David. Weston Park, Bath.
 1852. †Cheshire, Edward. Conservative Club, London.
 Cheshire, John.
 1853. *Chesney, Major-General Francis Rawdon, R.A., D.C.L., F.R.S.,
 F.R.G.S. Ballyardle, Kilkeel, Co. Down, Ireland.
 *Chevallier, Rev. Temple, B.D., F.R.A.S., Professor of Mathematics
 and Astronomy in the University of Durham.
 *Chichester, Ashurst Turner Gilbert, D.D., Lord Bishop of. 31
 Queen Anne-street, Cavendish-square, London; and The Palace,
 Chichester.
 1865. §Child, Gilbert W., M.D. Oxford.
 1842. *Chippindall, John.*
 1842. *Chiswell, Thomas. 2 Lincoln-grove, Plymouth-grove, Manchester.
 1863. §Cholmeley, Rev. C. H. Magdalen College, Oxford.
 1859. †Christie, John, M.D. 46 School-hill, Aberdeen.
 1861. †Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
 Christison, Robert, M.D., F.R.S.E., Professor of Dietetics, Materia
 Medica, and Pharmacy in the University of Edinburgh. Edin-
 burgh.
 1860. †Church, William Selby, M.A. 1 Harcourt Buildings, Temple, London.
 1850. †Churchill, Lord Alfred. Blenheim, Woodstock.
 1857. †Churchill, F., M.D. 15 Stephen's Green, Dublin.
 1863. †Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.
 1863. †Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
 1855. §Clapham, Robert Calvert. Wincomblee, Walker, Newcastle-on-Tyne.
 1858. †Clapham, Samuel. 17 Park-place, Leeds.
 1857. †Clarendon, Frederick Villiers. 11 Blessington-street, Dublin.
 *Clark, Rev. Charles, M.A. Queen's College, Cambridge.
 Clark, Courtney K. Haugh End, Halifax.
 1859. †Clark, David. Coupar Angus.
 *Clark, Francis.
 Clark, G. T. Bombay; and Athenæum Club, Pall Mall, London.
 1846. *Clark, Henry, M.D. 4 Upper Moira-place, Southampton.

Year of
Election.

- Clark, Sir James, Bart., M.D., M.A., F.R.S., F.R.G.S., Physician in Ordinary to the Queen. 22B Brook-street, Grosvenor-square, London.
1861. †Clark, Latimer. 1 Victoria-street, Westminster, London.
1855. †Clark, Rev. William, M.A. Barrhead, near Glasgow.
Clark, William, M.D., F.R.S., F.G.S. Cambridge.
1865. §Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
Clarke, George. Mosley-street, Manchester.
1861. *Clarke, J. H. Earncliffe, Alderley Edge.
1842. Clarke, Joseph. Waddington Glebe, Lincoln.
1851. †Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1848. §Claudet, Antoine, F.R.S. 11 Gloucester-road, Regent-park, London.
1861. †Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, Yorkshire.
1854. †Clay, Robert. St. Ann-street, Liverpool.
1855. †Clay, William.
1856. *Clay, William. 4 Park-hill-road, Liverpool.
1857. *Clayton, David Shaw. Norbury, Stockport, Cheshire.
1850. †Cleghorn, Hugh, M.D. Madras Establishment.
1859. †Cleghorn, John. Wick.
1861. †Cleland, John, M.D. Queen's College, Galway.
1857. †Clements, Henry. Dromin, Listowel, Ireland.
Cleddinning, Alexander, M.R.I.A.
- †Clerk, Rev. D. M. Deverill, Warminster, Wilts.
Clerke, Rev. C. C., D.D., Archdeacon of Oxford and Canon of Christ Church, Oxford. Milton Rectory, Abingdon, Berkshire.
1850. †Clerke, Right Honourable Sir George, Bart.
1852. †Clibborn, Edward. Royal Irish Academy, Dublin.
1865. §Clift, John E., C.E. Redditch.
1861. *Clifton, Professor R. B., B.A. Owens College, Manchester.
1849. †Clive, R. H. Hewell, Bromsgrove.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. †Close, The Very Rev. Francis, M.A. Carlisle.
Clough, Rev. Alfred B., B.D. Brandeston, Northamptonshire.
1859. †Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. Glasgow.
Clow, John.
1863. §Clutterbuck, Thomas. Warkworth, Acklington.
1855. *Coats, Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. 4 St. John's Villas, Haverstock-hill, Hampstead, London.
1851. *Cobbold, John Chevallier, M.P. Tower-street, Ipswich.
1864. §Cobbold, T. Spencer, M.D., F.R.S., F.L.S., Lecturer on Comparative Anatomy at the Middlesex Hospital. 84 Wimpole-street, Cavendish-square, London.
1845. †Cocker, John, M.A. Cambridge.
*Cocker, Jonathan. Higher Broughton, Manchester.
1854. †Cockey, William. 18 Lansdown-crescent, Glasgow.
1861. *Coe, Rev. Charles C. Leicester.
1864. *Cochrane, James Henry. Dunkathel, Glanmire, Co. Cork.
1865. §Coghill, H. Newcastle-under-Lyme.
1853. †Colchester, William, F.G.S. Dovercourt, near Harwich.
1859. †Cole, Edward. 11 Hyde Park-square, London.
1859. *Cole, Henry Warwick. 3 New-square, Lincoln's Inn, London.
1846. †Cole, Robert, F.S.A. 54 Clarendon-road, Notting-hill, London.
1860. †Coleman, J. J., F.C.S.

Year of
Election.

1854. *Colfox, William, B.A. Bridport, Dorsetshire.
 1857. †Colles, William, M.D. Stephen's Green, Dublin.
 1861. *Collie, Alexander. 23 Sussex-square, Hyde Park, London.
 1861. †Collinge, John.
 1854. †Collingwood, Cuthbert, M.A., M.B., F.L.S. 15 Oxford-street, Liverpool.
 1861. *Collingwood, J. Frederick, F.G.S. 54 Gloucester-street, Belgrave-road, Pimlico, London.
 1865. *Collins, James Tertius. 36 Cumberland-street, Birmingham.
 1849. †Collins, Joseph. Frederick-street, Edgbaston, Birmingham.
 Collins, J. V., M.R.D.S.
 Collins, Robert, M.R.D.S. Ardsallagh, Navan, Ireland.
 Collis, Stephen Edward. Listowel, Ireland.
 Colthurst, John. Clifton, Bristol.
 1865. *Combe, Thomas, M.A. Oxford.
 *Compton, Lord Alwyn. Castle Ashby, Northamptonshire.
 1846. *Compton, Lord William. 145 Piccadilly, London.
 1852. †Connal, Michael. 16 Lynedock-terrace, Glasgow.
 1853. †Constable, Sir T. C., Bart.
 1858. †Conybeare, Henry, F.G.S. 20 Duke-street, Westminster, London.
 *Conway, Charles. Pontnwydd Works, Newport, Monmouthshire.
 1864. *Conwell, Eugene Alfred, M.R.I.A. Trim, Ireland.
 1859. †Cook, E. R. Stamford-hill, London.
 1861. *Cook, Henry.
 Cooke, Captain Adolphus.
 **Cooke, A. B.*
 1863. §Cooke, Edward William, F.R.S., F.L.S., F.G.S., A.R.A. The Ferns, Hyde Park-gate, South Kensington, London.
 Cooke, James R., M.A. 73 Blessington-street, Dublin.
 1854. †Cooke, John. Howe Villa, Richmond, Yorkshire.
 Cooke, J. B. Exchange-buildings, Liverpool.
 Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
 1854. †Cooke, Rev. William, M.A. Gazeley Vicarage, near Newmarket.
 Cooke, William Fothergill. Telegraph Office, Lothbury, London.
 1859. *Cooke, William Henry, M.A., F.S.A. Elm-court, Temple, London.
 1865. §Cooksey, Joseph. West Bromwich, Birmingham.
 1862. *Cookson, Rev. H. W., D.D. St. Peter's College, Cambridge.
 1863. †Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
 1850. †Cooper, Sir Henry, M.D. 7 Charlotte-street, Hull.
 Cooper, James. 55 Pembroke Villas, Bayswater.
 1846. †Cooper, William White. 19 Berkeley-square, London.
 1865. §Cope, James. Pensnett, near Dudley.
 1856. †Copeland, George F., F.G.S., 5 Bay's-hill Villas, Cheltenham.
 1854. †Copland, James, M.D., F.R.S. 5 Old Burlington-street, London.
 Copland, William, F.R.S.E. Dumfries.
 1863. †Coppin, John. North Shields.
 1842. *Corbet, Richard. Hadington-hill, Oxford.
 1842. Corbett, Edward. Ravenoak, Chedale-hulme, Cheshire.
 1855. †Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology, Queen's College, Cork.
 Cormack, John Rose, M.D., F.R.S.E. 5 Bedford-square, London.
 1860. †Corner, C. Tinsley.
 Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
 Cottam, George. 2 Winsley-street, London.
 1857. †Cottam, Samuel. Brazennose-street, Manchester.
 Cotter, John. Cork.

Year of
Election.

1864. §Cotton, General F. C. Knolton Hall, Ruabon.
Cotton, William, D.C.L., F.R.S., F.S.A. Bank of England, London ;
and Walwood House, Leytonstone, London.
*Cotton, Rev. William Charles, M.A. New Zealand.
1865. §Couper, James. 12 Royal Exchange-square, Glasgow.
§Courtald, Samuel. Gosfield Hall, Essex.
*Courtney, Henry, M.R.I.A. 34 Fitzwilliam-place, Dublin.
Courtney, Richard. 118 Bagot-street, Dublin.
Cowan, John. Valleyfield, Pennyquick, Edinburgh.
1863. †Cowan, John A. Blaydon Burn, Durham.
1863. §Cowan, Joseph, jun. Blaydon, Durham.
Cowie, Rev. Benjamin Morgan, M.A. 42 Upper Harley-street,
Cavendish-square, London.
1860. †Cowper, Edward Alfred, M.I.C.E. Colne Cottage, Twickenham
Common, London.
1850. †Cox, John. Georgie Mills, Edinburgh.
*Cox, Joseph, F.G.S. Wisbeach, Cambridgeshire.
Cox, Robert. 26 Rutland-street, Edinburgh.
1847. †Cox, Rev. W. H., B.D. Eaton Bishop, Herefordshire.
1854. §Crace-Calvert, Frederick, Ph.D., F.R.S., F.C.S., Honorary Professor
of Chemistry to the Manchester Royal Institution. Royal In-
stitute, Manchester.
Craig, J. T. Gibson, F.R.S.E. Edinburgh.
1859. §Craig, S. Clayhill, Enfield, Middlesex.
1857. †Crampton, Rev. Josiah., M.R.I.A. The Rectory, Florence-court, Co.
Fermanagh, Ireland.
1858. †Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
Craven, Robert. Hull.
1852. †Crawford, Alexander, jun. Mount Prospect, Belfast.
1857. †Crawford, George Arthur, M.A.
1849. †Crawfurd, John, F.R.S., F.R.G.S. 4 Elvaston-place, Kensington ;
and Athenæum Club, Pall Mall, London.
1842. *Crewdson, Thomas D. Dacca Mills, Manchester.
Creyke, The Venerable Archdeacon. Beeford Rectory, Driffeld.
- *Crichton, William. 1 West India-street, Glasgow.
1854. †Crisp, M. F.
1865. §Crocker, Edwin, F.C.S. 2 Lonsdale-square, Islington, London.
Croft, Rev. John, M.A., F.C.P.S.
1858. †Crofts, John. Hillary-place, Leeds.
Croker, Charles Phillips, M.D., M.R.I.A. 7 Merrion-square West,
Dublin.
1859. †Croll, A. A. 10 Coleman-street, London.
1857. †Crolly, Rev. George. Maynooth College, Ireland.
1855. †Crompton, Charles, M.A. 22 Hyde Park-square, London.
*Crompton, Rev. Joseph, M.A. Norwich.
Crook, J. Taylor.
Crook, William Henry, LL.D.
Crooke, G. W.
1865. §Crookes, William, F.R.S., F.C.S. 20 Mornington-road, London.
1855. *Cropper, Rev. John. Stand, near Manchester.
1859. †Crosfield, John. Rothay Bank, Ambleside.
1861. †Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1853. †Crosskill, William, C.E. Beverley, Yorkshire.
1865. §Crotch, George Robert. Pearl-street, Cambridge.
1854. †Crowe, John. 3 Mersey Chambers, Liverpool.
1861. §Crowley, Henry. 255 Cheetham-hill-road, Manchester.
1863. §Crowthier, B. Wakefield.
1863. †Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.

Year of
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1860. †Cruickshank, John. City of Glasgow Bank, Aberdeen.
 1859. †Cruickshank, Provost. Macduff, Aberdeen.
 1859. †Crum, James. Busby, Glasgow.
 1855. §Crum, Walter, F.R.S., F.C.S. Thornliebank, near Glasgow.
 1849. †Cubitt, Thomas. Thames Bank, Pimlico, London.
 1851. †Cull, Richard. 13 Tavistock-street, Bedford-square.
 Culley, Robert. Bank of Ireland, Dublin.
 1859. †Cumming, Sir A. P. Gordon, Bart. Altyre.
 1847. †Cumming, Rev. J. G., M.A.
 1861. *Cunliffe, Edward Thomas. Handforth, Manchester.
 1861. *Cunliffe, Peter Gibson. Handforth, Manchester.
 1850. †Cunningham, James. 50 Queen-street, Edinburgh.
 1861. †Cunningham, James, F.R.S.E. Queen-street, Edinburgh.
 Cunningham, John. Liverpool.
 1852. †Cunningham, John. Macedon, near Belfast.
 1850. †Cunningham, Rev. William, D.D. 17 Salisbury-road, Edinburgh. ‡
 1855. §Cunningham, William A. Manchester and Liverpool District Bank,
 Manchester.
 1850. †Cunningham, Rev. W. B. Prestonpans, Scotland.
 1857. †Curtis, Professor Arthur Hill, LL.D. 6 Trinity College, Dublin.
 1834. *Cuthbert, J. R. 40 Chapel-street, Liverpool.
 Cuthbertson, Allan. Glasgow.

 1863. †Daglish, John. Hetton, Durham.
 1854. †Daglish, Robert, C.E. Orrell Cottage, near Wigan.
 1854. †Daglish, Robert, jun. St. Helen's, Lancashire.
 1863. †Dale, J. B. South Shields.
 1853. †Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
 1865. §Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
 Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
 1850. †Dalmahoy, Patrick. 69 Queen-street, Edinburgh.
 1859. †Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.
 1859. †Dalrymple, Colonel. Troup, Scotland.
 Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
 *Dalton, Rev. James Edward, B.D. Seagrave, Loughborough.
 1859. †Daly, Lieut.-Colonel H. D.
 1859. *Dalzell, Allen, M.D. The University, Edinburgh.
 Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfries-
 shire.
 1862. †Danby, T. W. Downing College, Cambridge.
 1859. †Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
 Daniel, Henry, M.D.
 Danson, Edward.
 1847. †Danson, John Towne.
 1849. *Danson, Joseph, F.C.S. 6 Shaw-street, Liverpool.
 Danson, William. 6 Shaw-street, Liverpool.
 1859. §Darbshire, Charles James. Rivington, near Chorley, Lancashire.
 1861. *Darbshire, Robert Dukinfield, B.A., F.G.S. 21 Brown-street, Man-
 chester.
 *Darbshire, Samuel D. Pendyffryn, near Conway.
 1852. †Darby, Rev. Jonathan L.
 Darwin, Charles R., M.A., F.R.S., F.L.S., F.G.S. Down, near Brom-
 ley, Kent.
 1854. †Dashwood, Charles.
 1848. §Da Silva, Johnson. Burntwood, Wandsworth Common.
 *Daubeny, Charles Giles Bridle, M.D., LL.D., F.R.S., F.L.S., F.G.S.,
 M.R.I.A., V.P.C.S., Professor of Botany in the University of
 Oxford. Oxford.

Year of
Election.

1859. †Daun, Robert, M.D., F.G.S., Deputy Inspector-General of Hospitals.
The Priory, Aberdeen.
Davey, Richard, M.P., F.G.S. Redruth, Cornwall.
1859. †Davidson, Charles. Grove House, Auchmull, Aberdeen.
1859. †Davidson, Patrick. Inchmarlo, near Aberdeen.
1847. †*Davidson, Rev. Samuel, LL.D.*
1863. †Davies, Griffith. 17 Cloudesley-street, Islington, London.
Davies, John Birt, M.D. The Laurels, Edgbaston, Birmingham.
Davies, Thomas.
1842. Davies, Dr. Thomas. Chester.
Davis, Charles, M.D., M.R.I.A. 33 York-street, Dublin.
1864. §Davis, Charles E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1856. *Davis, Sir John Francis, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood,
Compton Greenfield, near Bristol.
1859. †Davis, J. Barnard, M.D., F.S.A. Shelton, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London.
1863. *Davison, Joseph. Greencroft, Durham.
1864. §Davison, Richard. Great Driffield, Yorkshire.
1857. †Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near
Dublin.
1860. §Davy, John, M.D., F.R.S. L. & E. Lesketh How, near Amble-
side.
1854. *Dawbarn, William. Wisbeach, Cambridgeshire.
1859. †*Dawes, Captain (Adjutant R.A. Highlanders).*
Dawes, John Samuel, F.G.S. Smethwick House, near Birming-
ham.
1860. *Dawes, John T., jun. Smethwick House, near Birmingham.
1864. §Dawes, R., Dean of Hereford.
*Dawes, Rev. William Rutter, F.R.A.S. Haddenham, near Thame,
Oxon.
1864. †Dawkins, W. Boyd, B.A. 2 Bexley-road, Belvedere, Kent.
*Dawson, Christopher H. Low Moor, Bradford, Yorkshire.
1865. §Dawson, George, M.A. Shenstone, Lichfield.
*Dawson, Henry. 14 St. James's-road, Liverpool.
1855. §Dawson, J. W., LL.D., F.R.S., Principal of College, Montreal,
Canada.
Dawson, James.
Dawson, John. Royds Hall, Bradford, Yorkshire.
Dawson, Thomas. Glasgow.
1859. *Dawson, William G. Plumstead Common, Kent.
1865. §Day, Edward Charles H. Charmouth, Dorset.
1861. †Deacon, Henry. Runcorn Gap, Cheshire.
1859. †Dean, David. Banchory, Aberdeen.
1861. †Dean, Henry. Colne, Lancashire.
1854. §Deane, Henry, F.L.S. Clapham Common, London.
*Deane, Sir Thomas. Kingstown, Co. Dublin.
1851. †De Grey, The Hon. F. Copdock, Ipswich.
*De Grey and Ripon, George Frederick, Earl, F.R.S. 1 Carlton-
gardens, London.
1854. *De la Rue, Warren, Ph.D., F.R.S., F.R.A.S. Cranford, Middlesex;
and 110 Bunhill-row, London.
Denchar, John. Morningside, Edinburgh.
1854. †Denison, The Hon. William, M.P. Grinston, Tadcaster.
Denison, Sir William Thomas, Lieut.-Col. R.E., F.R.S., F.R.G.S.,
Governor of Madras. Madras.
1847. †*Dennis, J. C., F.R.A.S.*
1845. †*Denny, Henry.*

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- *Dent, Joseph. Ribston Hall, Wetherby.
Dent, William Yerbury. Royal Arsenal, Woolwich.
De Saumarez, Rev. Havilland, M.A. St. Peter's Rectory, Northampton.
De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
*Devonshire, William, Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London; and Chatsworth, Derbyshire.
1859. †Dewar, Rev. D., D.D., LL.D., Principal of Marischal College, Aberdeen.
1858. †Dibb, Thomas Townend. Little Woodhouse, Leeds.
1850. †Dick, Professor William. Veterinary College, Edinburgh.
1854. †Dicker, J. R. 29 Exchange-alley North, Liverpool.
1852. †Dickie, G., M.D., Professor of Natural History in Queen's College, Belfast.
1864. *Dickinson, F. H. Wingweston, Somerton, Taunton.
1863. †Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1853. *Dickinson, Joseph, M.D., F.R.S. 92 Bedford-street South, Liverpool.
1861. *Dickinson, W. L. 1 St. James's-street, Manchester.
1848. †Dickson, Peter. 28 Upper Brook-street, London.
1863. *Dickson, William, Clerk of the Peace for Northumberland. Alnwick, Northumberland.
*Dikes, William Hey, F.G.S. Wakefield.
*Dilke, Sir C. Wentworth, Bart., F.L.S., F.G.S., F.R.G.S. 76 Sloane-street, London.
1862. *Dilke, Charles Wentworth. 76 Sloane Street, London.
1848. †Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwern, near Swansea.
1859. *Dingle, Rev. J. Lanchester, Durham.
Dircks, Henry. 65 Basinghall-street, London.
1853. †Dixon, Edward, M.Inst.C.E. Wilton House, Southampton.
1854. †Dixon, Hugh. Devonshire House, Birkenhead.
1865. §Dixon, L. Hooton, Cheshire.
1858. †Dixon, *Isaiah*.
Dixon, Rev. W. H. Bishopthorpe, near York.
1861. †Dixon, W. Hepworth, F.S.A., F.R.G.S. Essex-villas, Queen's-road, St. John's-wood, London.
Dixon, William Joshua.
1859. †Dixon, *William Smith*.
*Dobbin, Leonard, jun., M.R.I.A. 27 Gardiner's-place, Dublin.
1851. †Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.
1860. †Dobbs, Archibald Edward. Balliol College, Oxford.
1864. *Dobson, William. Oakwood, Bathwick-hill, Bath.
Dockray, Benjamin. Lancaster.
1857. †Dodds, Thomas W., C.E. Rotherham.
*Dodsworth, Benjamin. St. Leonard's-place, York.
*Dodsworth, George. Clifton-grove, near York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. †Domville, William C., F.Z.S. Thorn-hill, Bray, Dublin.
*Donisthorpe, George Edmund. Holly Bank, Moortown, Leeds.
Donkin, J. R.
1860. †Donkin, William Fishburn, M.A., F.R.S., F.R.A.S., Savilian Professor of Astronomy in the University of Oxford. 34 Broad-street, Oxford.
1861. †Donnelly, Captain, R.E. South Kensington Museum, London.
1857. *Donnelly, William, C.B. Auburn, Malahide, Ireland.
1857. †Donovan, M., M.R.I.A. Clare-street, Dublin.

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1863. †Doubleday, Thomas. 25 Ridley-place, Newcastle-upon-Tyne.
 1863. *Doughty, C. Montague. Downing College, Cambridge.
 Douglas, James. Cavers, Roxburghshire.
 1855. §Dove, Hector. Rose Cottage, Trinity, near Edinburgh.
 Downall, Rev. John. Okehampton, Devon.
 *Downie, Alexander.
 1857. †Downing, S., LL.D., Professor of Civil Engineering in the University
 of Dublin. Dublin.
 1865. *Dowson, E. Theodore. Geldestone, near Beccles, Suffolk.
 1852. †Drennan, Dr. Chichester-street, Belfast.
 Drennan, William, M.R.I.A. 35 North Cumberland-street, Dublin.
 1865. §Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Man-
 chester.
 Drummond, David. Stirling.
 Drummond, H. Home, F.R.S.E. Blair Drummond, Stirling.
 1858. †Drummond, James. Greenock.
 1859. †Drummond, Robert. 17 Stratton-street, London.
 1863. †Dryden, James. South Benwell, Northumberland.
 1856. *Ducie, Henry John Reynolds Moreton, Earl of, F.R.S. 1 Belgrave-
 square, London; and Tortworth-court, Wotton-under-Edge.
 1835. †Duckett, Joseph F.
 1846. †Duckworth, William. Beechwood, near Southampton.
 1852. †Dufferin, The Rt. Hon. Lord. Highgate, London; and Clandeboyne,
 Belfast.
 1859. *Duncan, Alexander. Rhode Island, United States.
 1859. †Duncan, Charles. 52 Union-place, Aberdeen.
 *Duncan, James, M.D. Farnham House, Finglass, Co. Dublin.
 1861. †Duncan, James. Greenock.
 †Duncan, John W.
 Duncan, J. F., M.D. 19 Gardiner's-place, Dublin.
 Duncan, W. Henry, M.D. Liverpool.
 1848. †Dundas, Colonel, R.A.
 Dundas, Major-General Robert.
 Dunlop, Alexander. Clober, Milngavie, near Glasgow.
 1853. *Dunlop, William Henry. Annan-hill, Kilmarnock.
 1865. §Dunn, David. Annet House, Shelmorlie, by Greenock, N.B.
 1862. §Dunn, Robert, F.R.C.S. 31 Norfolk-street, Strand, London.
 Dunnington-Jefferson, Rev. Joseph, M.A., F.C.P.S. Thicket Hall,
 York.
 1857. †Du Noyer, George V. 51 Stephen's Green, Dublin.
 *Dunraven, Edwin, Earl of, F.R.S., F.R.A.S., F.G.S., F.R.G.S. Adare
 Manor, Co. Limerick; and Dunraven Castle, Glamorganshire.
 1859. †Duns, Rev. John, F.R.S.E. Torphichan, Bathgate, N. B.
 1852. †Dunville, William. Richmond Lodge, Belfast.
 1849. †Duppa, Duppa. Church Stretton, Shropshire.
 1860. †Durham, Arthur Edward, F.R.C.S., F.L.S., Demonstrator of Ana-
 tomy, Guy's Hospital, London.
 Durnford, Rev. R. Middleton, Lancashire.
 1851. †Durrant, C. M., M.D. Rushmere, Ipswich.
 1857. †Dwyer, Henry L., M.A., M.B. 67 Upper Sackville-street, Dublin.
 Dykes, Robert. Kilmore, Torquay, Devon.
 1861. †Eadson, Richard. 13 Hyde-road, Manchester.
 1864. †Earle, Rev. A. Rectory, Monkton Farleigh, Bat
 Earle, Charles, F.G.S.
 *Earnshaw, Rev. Samuel, M.A. Broomfield, Sheffield.
 {{{ §Easton, James. Nest House, near Gateshead, Durham.
 Eaton, Rev. George, M.A. The Pole, Northwich.

Year of
Election.

- Ebden, Rev. James C., M.A., F.R.A.S., F.C.P.S. Great Stukeley Vicarage, Huntingdonshire.
1861. †Ecroyd, William Farrer. Spring Cottage, near Burnley.
- *Eddison, Edwin. Headingley-hill, Leeds.
1858. *Eddison, Francis. North Laiths, Ollerton, Newark.
- *Eddy, James R., F.G.S. Carleton Grange, Skipton.
- Eden, Thomas. Riversdale-road, Aigburth, Liverpool.
1852. †Edgar, Rev. —, D.D. University-square, Belfast.
1861. †Edge, John William. Percy-street, Hulme, Manchester.
- *Edgeworth, Michael P., F.L.S., F.R.A.S. Mastrim House, Anerley, near London.
1855. †Edington, Thomas.
1855. †Edmiston, Robert. Elmbank-crescent, Glasgow.
1859. †Edmond, James. Cardens Haugh, Aberdeen.
1853. *Edmondston, Rev. John.
- Edward, Joshua.
- Edwards, James, B.A.
- Edwards, John. Halifax.
1855. *Edwards, J. Baker, Ph.D. Royal Institution Laboratory, Liverpool.
- *Egerton, Sir Philip de Malpas Grey, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
- Egginton, Samuel Hall. North Ferriby, Yorkshire.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.
1854. †Elcum, Charles Frederick. 3 Crescent-terrace, Cheltenham.
1855. †Elder, David. 19 Paterson-street, Glasgow.
1858. †Elder, John. 12 Centre-street, Glasgow.
- Ellacombe, Rev. H. T., F.S.A. Bilton, near Bristol.
1863. †Ellenberger, J. L. Worktop.
1855. §Elliot, Robert. Wolflee, Hawick.
1861. *Elliot, Sir Walter. Wolflee, Hawick.
1864. †Elliott, E. B. Washington, United States.
1862. §Elliott, Frederick Henry, M.A. 449 Strand, London.
- Elliott, John Fogg. Elvet-hill, Durham.
1859. †Ellis, Henry S., F.R.A.S. Fair Park, Exeter.
1857. †Ellis, Hercules. Lisnaroc, Clones, Ireland.
1864. *Ellis, Alexander John, B.A., F.R.S. 2 Western-villas, Colney Hatch Park, London.
1864. *Ellis, Joseph. Brighton.
1864. §Ellis, J. W. High House, Thornwaite, Ripley, Yorkshire.
- *Ellis, Rev. Robert, A.M. Grimstone House, near Malton, Yorkshire.
- Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
- Ellman, Robert Harvey.
1862. †Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London.
- Eltoft, William. Care of J. Thompson, Esq., 30 New Cannon-street, Manchester.
1856. †Elwait, Mons., LL.D.
1863. †Embleton, Dennis, M.D. Northumberland-street, Newcastle-upon-Tyne.
1863. †Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. †Empson, Christopher. Headingley, near Leeds.
1853. †English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
- Enniskillen, William Willoughby, Earl of, D.C.L., F.R.S., M.R.I.A., F.G.S. 32A Mount-street, Grosvenor-square, London; and Florence Court, Fermanagh, Ireland.
- *Enys, John Samuel, F.G.S. Enys, Cornwall.

Year of
Election.

- *Erle, Rev. Christopher, M.A., F.G.S. Hardwick Rectory, near Aylesbury.
1864. *Esrigge, R. A. 24 Albany, Old Hall-street, Liverpool.
1862. *Esson, William, M.A. Ness House, Cheltenham.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
Eustace, John, M.D.
1865. *Evans, Rev. Charles, M.A. King Edward's School, New-street, Birmingham.
1854. †Evans, Edward. Rock Ferry, Liverpool.
1849. *Evans, George Fabian, M.D. Waterloo-street, Birmingham.
1848. §Evans, Griffith F. D., M.D. Trewern, near Welshpool, Montgomeryshire.
1861. *Evans, John, F.R.S., F.S.A., F.G.S. Nash Mills, Hemel Hempstead.
1865. §Evans, Sebastian, M.A. Highgate, near Birmingham.
1865. *Evans, William. Chad-road, Edgbaston, Birmingham.
Evanson, R. T., M.D. Holme Hurst, Torquay.
1854. †Everest, A. M. Robert. 11 Reform Club, London.
Everest, Dr.
1840. §Everest, Colonel Sir George, C.B., F.R.S., F.R.A.S., V.P.R.G.S. 10 Westbourne-street, Hyde Park.
1863. *Everitt, George Allen, F.R.G.S., Belgian Consul. Birmingham.
Ewart, William, 6 Cambridge-square, Hyde Park, London; and Broadlands, Devizes.
1859. *Ewing, Archibald Orr. Clermont House, Glasgow.
1855. *Ewing, William. 209 Brandon-place, West George-street, Glasgow.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, Knightsbridge, London; and Warren's, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.
1849. †Eyton, T. C. Eyton, near Wellington, Salop.
1842. Fairbairn, Thomas. Manchester.
- *Fairbairn, William, C.E., LL.D., F.R.S., F.R.G.S. Manchester.
1865. §Fairley, Thomas. Medical School, Leeds.
1864. §Falkner, F. H. Lyncombe, Bath.
Fannin, John, M.A. 41 Grafton-street, Dublin.
- *Faraday, †Michael, D.C.L., LL.D., F.R.S., F.G.S., M.R.I.A., Ful-
lerian Professor of Chemistry in the Royal Institution of Great
Britain. 21 Albemarle-street, London.
1859. †Farquharson, Robert O. Houghton, Aberdeen.
1861. §Farr, William, M.D., D.C.L., F.R.S., Superintendent of the Statis-
tical Department General Registry Office, London. Southlands,
Bickley, Kent.
1857. †Farrelly, Rev. Thomas. Royal College, Maynooth.
1859. *Faulkner, Charles, F.S.A., F.G.S., F.R.G.S. Museum, Deddington,
Oxon.
1859. *Fawcett, Henry, M.P., Professor of Political Economy in the Univer-
sity of Cambridge. Trinity Hall, Cambridge.
1854. †Fawcett, John.
1863. §Fawcus, George. Alma-place, North Shields.
1846. †Featherstonhaugh, George William, F.R.S., F.G.S. Havre.
1845. †Felkin, William, F.L.S. Nottingham-park.
Fell, John B. Ulverston, Lancashire.
1864. §Fellowes, Frank P. Hampstead, London.
1852. †Fenton, Samuel Greame. 9 College-square, Belfast; and Keswick,
near Belfast.
1855. †Ferguson, James. Gas Coal-works, Lesmahago, Glasgow.
1859. †Ferguson, John. Cove, Nigg, Inverness.

Year of
Election.

1855. †*Ferguson, Peter.*
 1857. †Ferguson, Samuel. 20 North Great George-street, Dublin.
 1854. †Ferguson, William, F.L.S., F.G.S. 2 St. Aiden's-terrace, Birkenhead.
 1863. *Ferne, John. Clarence Iron Works, Leeds.
 Ferrall, J. M., M.D., M.R.I.A. 35 Rutland-square, Dublin.
 1862. †Ferrers, Rev. N. M., M.A. Caius College, Cambridge.
 Ferrier, Alexander James. 69 Leeson-street, Dublin.
 Feversham, William, Lord. Duncombe-park, Yorkshire.
 Field, Edwin W. 36 Lincoln's Inn Fields, London.
 Fielden, William.
 Fielding, G. H., M.D. Tunbridge, Kent.
 1854. †Fielding, James. Mearclough Mill, Sowerby Bridge, near Halifax.
 Finch, Charles. Cambridge.
 1864. §Finch, Frederick George, B.A., F.G.S. Blackheath Park, London.
 Finch, John. Bridge Work, Chepstow.
 Finch, John, jun. Bridge Work, Chepstow.
 1859. †Findlay, Alexander George, F.R.G.S. 53 Fleet-street, London;
 and Hayes, Kent.
 Finlay, James.
 1863. †Finney, Samuel. Sheriff-hill Hall, Newcastle-upon-Tyne.
 Firth, Thomas. Northwick.
 1854. †*Fischel, Rev. Arnold, D.D.*
 1851. *Fischer, William L. F., M.A., Professor of Natural Philosophy
 the University of St. Andrews, Scotland.
 1858. †Fishbourne, Captain E. G., R.N., F.R.G.S. 6 Welamere-terrace,
 Paddington, London.
 Fisher, Rev. John Hutton, M.A., F.G.S., F.C.P.S. Kirkby Lons-
 dale, Westmoreland.
 1858. †Fishwick, Captain Henry. Carr-hill, Rochdale.
 1857. †Fitzgerald, Lord Otho. 13 Dominick-street, Dublin.
 1857. †Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
 Fitzwilliam, Hon. George Wentworth, M.P., F.R.G.S. 19 Grosve-
 nor-square, London; and Wentworth House, Rotherham.
 1865. §Fleetwood, D. J. 45 George Street, St. Paul's, Birmingham.
 Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood,
 Lancashire.
 1850. †Fleming, Professor Alexander, M.D. 20 Temple Row, Birmingham.
 Fleming, Christopher, M.D. Merrion-square North, Dublin.
 1842. *Fleming, John, M.A.*
 1855. †Fleming, John. 31 Whitevale, Glasgow.
 Fleming, John G., M.D. 155 Bath-street, Glasgow.
 *Fleming, William, M.D. Rowton Grange, near Chester.
 Fletcher, Edward. 4 India-buildings, Liverpool.
 1853. †Fletcher, Isaac, F.R.S., F.R.A.S. Tarn Bank, Workington.
 Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
 Flood, Rev. James Charles.
 1862. †Flower, William Henry, F.R.S., F.L.S., F.G.S., F.R.C.S. Royal
 College of Surgeons, Lincoln's Inn-fields, London.
 1854. *Forbes, David, F.R.S., F.G.S. 12 York-place, Portman-square,
 London.
 Forbes, George, F.R.S.E.
 *Forbes, James David, LL.D., F.R.S. L. & E., F.G.S., Principal of
 the University of St. Andrews. Pitlochrie.
 1855. †Forbes, Rev. John. Symington Manse, Biggar, Scotland.
 1855. †Forbes, Rev. John, D.D. 150 West Regent-street, Glasgow.
 Forbes, Sir John Stuart, Bart., F.R.S.E. Fettercairn House, Kin-
 cardineshire.
 1856. †Forbes, Colonel Jonathan. 12 Lansdowne-terrace, Cheltenham.

Year of
Election.

- Ford, H. R. Morecombe Lodge, Yealand Congers, Lancashire.
Ford, John.
 Formby, Richard, M.D. Sandon-terrace, Liverpool.
 *Forrest, William Hutton. Stirling.
 1849. †Forster, Thomas Emerson. 7 Ellison-place, Newcastle-upon-Tyne.
 *Forster, William. Ballynure, Clones, Ireland.
 1858. †Forster, William Edward. Burley, Otley, near Leeds.
 1854. *Fort, Richard, F.G.S. Read Hall, Whalley, Lancashire.
 1865. §Foster, Balthazar W., M.D., F.L.S. 4 Old Square, Birmingham,
 *Foster, Charles Finch. Mill-lane, Cambridge.
 1865. *Foster, Clement Le Neve, D.Sc., F.G.S. High Cross, Truro.
 1845. †Foster, Ebenezer. The Elms, Cambridge.
 1857. *Foster, George C., B.A., F.C.S., Professor of Experimental Physics
 in University College, London.
 *Foster, H. S. Cambridge.
 *Foster, Rev. John, M.A. The Oaks Parsonage, Loughborough, Lei-
 cestershire.
 1845. †Foster, John N. St. Andrews, Biggleswade.
 1859. *Foster, Michael, M.D. Huntingdon.
 1859. §Foster, Peter Le Neve, M.A. Society of Arts, Adelphi, London.
 1863. †Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
 Foster, R. Brooklands, Cambridge.
 1859. *Foster, S. Lloyd. Old Park Hall, Walsall, Staffordshire.
 1842. *Fothergill, Benjamin.*
 1856. †Fowler, Rev. Hugh, M.A. College-gardens, Gloucester.
 1859. †Fowler, Rev. J. C., LL.D., F.A.S. Scotl. The Manse, Ratho, by
 Edinburgh.
 *Fowler, Robert. Rathmolyon, Co. Meath, Ireland.
 Fox, Alfred. Falmouth.
 1842. *Fox, Charles. Trebah, Falmouth.
 *Fox, Rev. Edward, M.A. The Vicarage, Romford, Essex.
 *Fox, Joseph Hayland. Wellington, Somerset.
 1860. †Fox, Joseph John. Church-row, Stoke Newington, London.
 *Fox, Robert Barclay. Falmouth.
 Fox, Robert Were, F.R.S. Falmouth.
 *Fox, Samuel Lindoe. Tottenham.
 1848. †Francis, George Grant, F.S.A. Burrows Lodge, Swansea.
 Francis, William, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court,
 Fleet-street, London; and 1 Matson Villas, Marsh-gate, Rich-
 mond, Surrey.
 1846. †Frankland, Edward, Ph.D., F.R.S., Professor of Chemistry in the
 Royal Institution and St. Bartholomew's Hospital. 42 Park-
 road, St. John's Park, Haverstock-hill, London.
 *Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
 Franks, Rev. J. C., M.A. Whittlesea, near Peterborough.
 1859. †Fraser, George B. Dundee.
 Fraser, James. 25 Westland-row, Dublin.
 Fraser, James William. 8a Kensington Palace-gardens, London.
 1865. *Fraser, John, M.A., M.D. 30 Darlington-street, Wolverhampton.
 1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
 1860. †Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
 1847. *Freeland, Humphrey William, F.G.S. The Athenæum Club, Pall
 Mall, London.
 1865. §Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
 1855. †Frere, Captain, R.A.
 Frere, George Edward, F.R.S. Royden Hall, Diss, Norfolk.
 1856. *Frerichs, John Andrew. 1 Keynsham Bank, Cheltenham.
Fripp, George D., M.D.

Year of
Election.

1857. *Frith, Richard Hastings, C.E. 51 Leinster-road, Rathmines, Dublin.
 1863. *Frith, William. Burley Wood, near Leeds.
 Frost, Charles, F.S.A. Hull.
 1847. †Frost, William, F.R.A.S. Wentworth Lodge, Upper Tulse-street.
 1860. *Froude, William. Emsleigh Paignton, Torquay.
 Fry, Francis. Cotham, Bristol.
 Fry, Richard. Cotham, Bristol.
 Fry, Robert. Tockington, Gloucestershire.
 1863. †Fryar, Mark. Eaton Moor Colliery, Newcastle-on-Tyne.
 *Fullarton, Allan. 19 Woodside-place, Glasgow.
 1859. †Fuller, Frederick, M.A., Professor of Mathematics in University and
 King's College, Aberdeen.
 1852. †Ferguson, Professor John C., M.A., M.B. Queen's College, Belfast.
 Furlong, Rev. Thomas, M.A. 10 Sydney-place, Bath.
 1864. *Furneaux, Rev. A. St. Germain's Parsonage, Cornwall.

 *Gadesden, Augustus William, F.S.A. Leigh House, Lower Tooting,
 Surrey.
 1854. †Gage, M. A., C.E.
 1857. †Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.
 1863. *Gainsford, W. D. Darnall Hall, Sheffield.
 Gair, S. S.
 1850. †Gairdner, W. F., M.D. 18 Hill-street, Edinburgh.
 1861. †Galbraith, Andrew. Glasgow.
 Galbraith, Rev. J. A., M.R.I.A. Trinity College, Dublin.
 1863. §Gale, Samuel, F.C.S. 338 Oxford-street, London.
 1861. †Galloway, Charles John. Knott Mill Iron Works, Manchester.
 1859. †Galloway, James. Calcutta.
 1861. †Galloway, John, jun. Knott Mill Iron Works, Manchester.
 Galloway, S. H. Linbach, Austria.
 1860. *Galton, Captain Douglas, R.E., F.R.S., F.G.S., F.R.G.S. 12 Ches-
 ter-street, Grosvenor-place, London.
 1860. *Galton, Francis, F.R.S., F.G.S., F.R.G.S. (*General Secretary.*) 42
 Rutland-gate, Knightsbridge, London.
 1842. Gardiner, Lot. Bradford, Yorkshire.
 1862. §Garner, Robert, F.L.S. Stoke-upon-Trent.
 1865. §Garner, Mrs. Robert. Stoke-upon-Trent.
 1842. Garnett, Jeremiah. Warren-street, Manchester.
 1852. †Garret, James R. Holywood, Belfast.
 1854. †Garston, Edgar. Aigburth, Liverpool.
 1847. *Gaskell, Samuel. 19 Whitehall-place, London.
 1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
 1846. §Gassiot, John Peter, V.P.R.S. Clapham Common, London.
 1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East
 Grinstead, Sussex.
 1859. †Geddes, William D., Professor of Greek, King's College, Old Aberdeen
 1854. †Gee, Robert, M.D. Oxford-street, Liverpool.
 1855. †Gemmell, Andrew. 38 Queen-street, Glasgow.
 1855. †Gemmell, Thomas. 12 Elmbank-crescent, Glasgow.
 1854. §Gerard, Henry. 13 Rumford-place, Liverpool.
 1856. *Gething, George Barkley. Springfield, Newport, Monmouthshire.
 Gibb, Duncan. Strand-street, Liverpool.
 1863. *Gibb, George D., M.D., M.A., LL.D., F.G.S. 19A Portman-street,
 Portman-square, London.
 Gibbins, Joseph. Birmingham.
 Gibbins, Thomas. Birmingham.
 1865. §Gibbins, William. Battery Works, Digbeth, Birmingham.
 Gibson, Edward. Hull.

Year of
Election.

- *Gibson, George Stacey. Saffron Walden.
 1852. †Gibson, James.
 1847. §Gibson, Thomas Field, F.G.S. 124 Westbourne-terrace, Hyde-park, London.
 1859. †Gibson, William Sidney, M.A., F.S.A., F.G.S. Tynemouth.
 1861. †Gifford, George, His Grace The Earl of, F.R.G.S. 2 Wilton-street, Grosvenor-place, London.
 1849. †Gifford, Rev. E. H. Birmingham.
 1842. Gilbert, Dr. J. H. Harpenden, near St. Albans.
 1861. *Gilbert, James Montgomery. Bowdon, Cheshire.
 1857. †Gilbert, J. T. Blackrock, Dublin.
 1859. †Gilchrist, James, M.D. Crichton Royal Institution, Dumfries.
 Gilderdale, Rev. John, M.A. Walthamstow, Essex.
 Giles, Rev. William. Netherleigh House, near Chester.
 1864. §Gill, Thomas. (*Local Treasurer.*) 4 Sydney-place, Bath.
 1850. †Gillespie, Alexander, M.D. Edinburgh.
 1854. †Gillis, F. L.
 1849. †Gilpin, Benjamin. Newcastle-on-Tyne.
 1861. †Gilroy, George. Hindley House, Wigan.
 1850. *Gladstone, George, F.C.S. Clapham Common, London.
 1849. *Gladstone, John Hall, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London.
 1861. *Gladstone, Murray. Broughton, Manchester.
 1852. †Gladstone, Thomas Murray.
 1861. *Glaisher, James, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, Kent.
 1853. †Gleadon, Thomas Ward. Moira-buildings, Hull.
 1859. †Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's Inn, London.
 Glover, George. Ranelagh-road, Pimlico, London.
 1852. †Godwin, John. Wood House, Rostrevor, Belfast.
 1846. †Godwin-Austen, Robert A.C., B.A., F.R.S., F.G.S. Chilworth Manor, Guildford.
 Goldsmid, Sir Francis Henry, M.P. 62 Portland-place, London.
 1842. Gooch, Thomas L.
 1857. †Good, John. 50 City Quay, Dublin.
 1852. †Goodbody, Jonathan. Clare, King's County, Ireland.
 1842. *Goodman, John, M.D. The Promenade, Southport.
 1865. §Goodman, J. D. Minorities, Birminham.
 1850. *Goodsir, John, F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 21 Lothian-street, Edinburgh.
 Goodwin, Very Rev. Harvey, D.D., F.C.P.S., Dean of Ely. Caius College, Cambridge.
 1859. †Gordon, H. G.
 *Gordon, Rev. James Crawford, M.A. Delamont, Downpatrick, Downshire.
 1857. †Gordon, Samuel, M.D. 11 Hume-street, Dublin.
 1865. §Gore, George, F.R.S. 50 Islington-row, Edgbaston, Birmingham.
 *Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
 *Gotch, Thomas Henry. Ilford, Essex.
 1849. †Gough, The Hon. Frederick. Perry Hall, Birmingham.
 1857. †Gough, The Hon. G. S. Rathronan House, Clonmel.
 Gould, John, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London.
 1854. †Gourley, Daniel De la C., M.D.
 Gowland, James. London-wall, London.
 *Græme, James.
 1861. †Grafton, Frederick W. Park-road, Whalley Range, Manchester.
 1848. †Graham, John B.

Year of
Election.

- Graham, Lieutenant David. Mecklewood, Stirlingshire.
 *Graham, Thomas, M.A., D.C.L., F.R.S. L. & E., F.G.S., V.P.C.S.,
 Master of the Mint. 4 Gordon-square, London.
1852. *Grainger, John. Rose Villa, Belfast.
 Grainger, Richard. Newcastle-upon-Tyne.
1850. †*Grainger, Thomas.*
1859. †Grant, Hon. James. Cluny Cottage, Forres.
1855. §Grant, Robert, M.A., F.R.A.S., Regius Professor of Astronomy in the
 University of Glasgow. The Observatory, Glasgow.
1854. †*Grantham, John, C.E.*
1864. †Grantham, Richard F. 7 Great Scotland-yard, London.
1854. †Grantham, R. B. 7 Great Scotland-yard, London.
 Granville, Augustus Bozzi, M.D., F.R.S., F.G.S., M.R.I.A. 5 Corn-
 wall-terrace, Warwick-square, Pimlico, London.
1854. †Gravatt, William, F.R.S. 15 Park-street, Westminster.
 *Graves, Very Rev. Charles, D.D., M.R.I.A. Dublin Castle, Dublin.
 *Graves, Rev. Richard Hastings, D.D. Brigown Glebe, Michelstown,
 Co. Cork.
1864. *Gray, Rev. Charles. Trinity College, Cambridge.
1865. §Gray, Charles. Swan-bank, Bilston.
 **Gray, John.*
1857. †Gray, John, M.D. Rathgar, Dublin.
 *Gray, John. Greenock.
 *Gray, John Edward, Ph.D., F.R.S., Keeper of the Zoological Col-
 lections of the British Museum. British Museum.
1864. †Gray, Jonathan. Summerhill-house, Bath.
1859. †Gray, Rev. J. H. Bolsover Castle, Derbyshire.
 *Gray, William, F.G.S. (*Local Treasurer.*) Minster Yard, York.
1861. *Gray, W., M.P. Darcey Lever Hall, Bolton.
1854. *Grazebrook, Henry, jun. 37 Falkner-square, Liverpool.
 Green, Rev. Henry. Heathfield, Knutsford, Cheshire.
 *Greenaway, Edwrad. 16 Lansdowne-crescent, Notting-hill, Lon-
 don.
1857. †Greene, Professor J. Reay, Queen's College, Cork. 5 Ebenezer-ter-
 race, Cork.
1845. †*Greene, Richard, M.D.*
1858. *Greenhalgh, Thomas. Astley House, Sharples, near Bolton-le-Moors.
Greenler, Matthew.
1863. †Greenwell, G. E. Poynton, Cheshire.
1862. §Greenwood, Henry. Huyton Park, Huxton, near Liverpool.
1849. †Greenwood, William. Stones, Todmorden.
1861. *Greg, Robert Philips, F.G.S. (*Local Treasurer.*) Outwood Lodge,
 near Manchester.
 Gregg, T. H. 22 Ironmonger-lane, Cheapside.
1860. †Gregor, Rev. Walter, M.A. Pitsligo, Roseheart, Aberdeenshire.
1861. §Gregson, Samuel Leigh. Aighurth, near Liverpool.
 Gresham, Thomas M. Raheny, Dublin.
- *Greswell, Rev. Richard, B.D., F.R.S., F.R.G.S. St. Giles's-street,
 Oxford.
 Greville, R. K., LL.D., F.R.S.E. Edinburgh.
- Grey, Captain The Hon. Frederick William. Howick, Northumberland.
1863. †Grey, W. S. Norton, Stockton-on-Tees.
1859. †Grierson, Thomas Boyle. Thornhill, Dumfriesshire.
1855. †*Griffin, Charles.*
 *Griffin, John Joseph, F.C.S. Garrick-street, London.
Griffin, S. F.
Griffin, Thomas.
 Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.

Year of
Election.

1859. *Griffith, George, M.A., F.C.S. (*Assistant General Secretary*). 5 Park Villas, Oxford.
Griffith, George R. Fitzwilliam-place, Dublin.
*Griffith, Sir Richard, Bart., LL.D., F.R.S.E., M.R.I.A., F.G.S. 2 Fitzwilliam-place, Dublin.
1847. †Griffith, Thomas. Bradford-street, Birmingham.
Griffith, Walter H., M.A. 13 Clare-street, Dublin.
Griffiths, Rev. John, M.A. 63 St. Giles's, Oxford.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
Grove, William Robert, Q.C., M.A., Ph.D., (PRESIDENT ELECT), F.R.S. 46 Upper Harley-street; and 4 Hare-court, Temple, London.
1849. †Grover, Rev. H. M.
1863. §Groves, Thomas B. Weymouth, Dorset.
1857. †Grubb, Thomas, F.R.S., M.R.I.A. Bank of Ireland, Dublin.
Guest, Edwin, LL.D., M.A., F.R.S., F.L.S., F.R.A.S., Master of Caius College, Cambridge. Caius Lodge, Cambridge; and Sandford-park, Oxfordshire.
- Guinness, Henry. 26 South Frederick-street, Dublin.
1842. Guinness, Richard Seymour. 26 South Frederick-street, Dublin.
*Guinness, Rev. William Smyth, M.A. Beaumont, Drumcondra, Co. Dublin.
1856. *Guise, Sir William Vernon, Bart., F.G.S., F.L.S. Elmore-court, near Gloucester.
1862. †Gunn, Rev. John, M.A. Irstedd Rectory, Norwich.
1860. *Gurney, Samuel, M.P., F.R.G.S. 25 Princes-gate, London.
*Gutch, John James. 88 Micklegate, York.
1850. †Guthrie, Frederick. University of Edinburgh.
1864. §Guyon, George. South Cliff Cottage, Ventnor, Isle of Wight.
1857. †Gwynne, Rev. John. St. Columbe's College, Dublin.
- Hackett, Michael. Brooklawn, Chapelizod, Dublin.
1865. §Hackney, William. 3 Great George-street, Westminster.
Hackworth, Timothy. Darlington.
1865. §Haden, W. H. Cawney Bank Cottage, Dudley.
1862. †Haddon, Frederick William, Assistant-Secretary to the Statistical Society of London. 12 St. James's-square, London.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George, M.P. Victoria-park, Manchester.
1848. †Hadland, William Jenkins. Banbury, Oxfordshire.
*Hailstone, Edward, F.S.A. Horton Hall, Bradford, Yorkshire.
Haire, James, M.A.
- Halifax, The Right Hon. Viscount. 10 Belgrave-square, London; and Hickleston Hall, Doncaster.
1845. †Hall, Elias. Castleton, Derbyshire.
1854. *Hall, Hugh Fergus. 17 Dale-street, Liverpool.
1859. †Hall, John Frederic. Ellerker House, Richmond, Surrey.
Hall, John R. Sutton, Surrey.
1863. †Hall, Thomas Y. Eldon-square, Newcastle-on-Tyne.
*Hall, T. B. Coggeshall, Essex.
1860. §Hall, Walter. 10 Pier-road, Erith.
Halliday, A. H., M.A., F.L.S., M.R.I.A. Carnmoney, Antrim, Ireland.
1861. †Halliday, James. Whalley Court, Whalley Range, Manchester.
1857. †Halpin, George, C.E.
Halsall, Edward. Bristol.
Halswell, Edmund S., M.A.
1858. *Hamblly, Charles Hamblly Burbridge, F.G.S. 96 London-road, Leicester.

Year of
Election.

1846. † *Hambrough, A. J.*
 1857. † Hamilton, Charles W. 40 Dominick-street, Dublin.
 1865. § Hamilton, Gilbert. Leamington.
 Hamilton, The Very Rev. Henry Parr, Dean of Salisbury, M.A.,
 F.R.S. L. & E., F.G.S., F.R.A.S. Salisbury.
 *Hamilton, Mathie, M.D. Warwick-street, Glasgow.
 1864. § Hamilton, Rev. S. R., M.A. Hinton Lodge, Bournemouth.
 1840. *Hamilton, William John, F.R.S., F.G.S. 23 Chesham-place, Bel-
 grave-square, London.
 1851. † Hammond, C. C. Lower Brook-street, Ipswich.
 1863. † Hancock, Albany, F.L.S. 4 St. Mary's-terrace, Newcastle-upon-
 Tyne.
 1852. † *Hancock, Charles Brownlow.*
 1863. † Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
 1850. § Hancock, John. Manor House, Lurgan, Co. Armagh.
 1861. † Hancock, Walker. 10 Upper Chadwell-street, Pentonville, London.
 1857. † Hancock, William J. 74 Lower Gardiner-street, Dublin.
 1847. † Hancock, W. Nelson, LL.D. 74 Lower Gardiner-street, Dublin.
 1865. § Hands, M. Coventry.
 Handyside, P. D., M.D., F.R.S.E. 11 Hope-street, Edinburgh.
 1859. † Hannay, John. Montcoffer House, Aberdeen.
 1853. † Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
 *Harcourt, A. Vernon, M.A., F.C.S. Christ Church, Oxford.
 Harcourt, Rev. C. G. Vernon, M.A. Rothbury, Northumberland.
 Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, York-
 shire.
 *Harcourt, Rev. William V. Vernon, M.A., F.R.S., F.G.S., Hon. M.R.I.A.
 Nuneham Park, Oxford.
 1849. † Harding, Charles. Tamworth.
 1865. § Harding, Charles. Harborne Heath, Birmingham.
 1864. § Hardwicke, Robert. 192 Piccadilly, London.
 1858. *Hardy, Charles. Odsall House, Bradford, Yorkshire.
 *Hare, Charles John, M.D., Professor of Clinical Medicine in Uni-
 versity College, London. 41 Brook-street, Grosvenor-square,
 London.
 Hare, Samuel. 9 Langham-place, London.
 Harford, John Scandrett, D.C.L., F.R.S., F.G.S. Blaise Castle,
 Bristol.
 Harford, Summers. Reform Club, London.
 1858. † Hargrave, James. Burley, near Leeds.
 1853. § Harkness, Robert, F.R.S. L. & E., F.G.S., Professor of Geology in
 Queen's College, Cork.
 Harkworth, Timothy. Soho Shilden, Darlington.
 1862. *Harley, George, M.D., F.C.S., Professor of Practical Physiology and
 Histology in University College, London.
 *Harley, John. Ross Hall, near Shrewsbury.
 1862. *Harley, Rev. Robert, F.R.S., F.R.A.S., Professor of Mathematics
 and Logic in Airedale College, Bradford. The Manse, Brighouse,
 Yorkshire.
 1861. † Harman, H. W., C.E. 16 Booth-street, Manchester.
 *Harris, Alfred. Ryshwall Hall, near Bingley, Yorkshire.
 *Harris, Alfred, jun. Bradford, Yorkshire.
 1863. † Harris, Charles. 6 Somerset-terrace, Newcastle-on-Tyne.
 Harris, The Hon. and Rev. Charles, F.G.S. Bremhill, Chippenham,
 Wiltshire.
 1842. * *Harris, George William.*
 *Harris, Henry. Heaton Hall, near Bradford.
 1845. † Harris, Henry H. Cambridge.

Year of
Election.

1863. †Harris, T. W. Grange, Middlesborough-on-Tees.
Harris, Sir William Snow, F.R.S. Windsor Villas, Plymouth.
1862. †Harris, William Harry, F.C.S. 33 Gold-street, Northampton.
1860. †Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. §Harrison, George. Barnsley.
1858. *Harrison, James Park, M.A. Garlands, Ewhurst, Surrey.
Harrison, Robert, M.D., Professor of Anatomy and Surgery in the
University of Dublin. 1 Hume-street, Dublin.
1853. †Harrison, Robert. 36 George-street, Hull.
1863. §Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-
Tyne.
1853. *Harrison, William, F.S.A., F.G.S. Galligreaves Hall, near Black-
burn, Lancashire.
1849. †Harrowby, The Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-
square, London; and Sandon Hall, Lichfield.
1859. *Hart, Charles. 54 Wych-street, Strand, London.
Hart, John, M.D., M.R.I.A. 3 Bloomfield-avenue, Dublin.
1861. *Harter, J. Collier. Chapel Walks, Manchester.
1842. *Harter, William. Hope Hall, Manchester.
1856. †Hartland, F. Dixon, F.S.A., F.R.G.S. The Oaklands, near Chel-
tenham.
Hartley, James. Sunderland.
Hartley, J. B. Bootle, near Liverpool.
Hartnell, Aaron.
Hartnell, M. A., B.A.
1854. §Hartnup, John, F.R.A.S. The Observatory, Liverpool.
1850. †Harvey, Alexander. 4 South Wellington-place, Glasgow.
*Harvey, Joseph Charles. Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Mayfield, Bolton-le-moors.
1855. †Hassall, Arthur Hill. 8 Bennett-street, St. James's, London.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1842. *Hatton, James. Richmond House, Higher Broughton, Manchester.
1863. §Hatton, James W. Old Lodge, Old Trafford, Manchester.
Haughton, James, M.R.D.S. 34 Eccles-street, Dublin.
1857. †Haughton, Rev. Samuel, M.D., M.A., F.R.S., M.R.I.A., F.G.S., Pro-
fessor of Geology in the University of Dublin. Trinity College,
Dublin.
1857. †Haughton, S. Wilfred. Grand Canal-street, Dublin.
*Haughton, William. 28 City Quay, Dublin.
1845. †Haviland, John, M.D. Cambridge.
1856. †Haville, Henry.
1847. †Hawkins, Rev. Edward, D.D., Provost of Oriel College, Oxford.
Hawkins, John Heywood, M.A., F.R.S., F.G.S. Bignor Park, Pet-
worth, Sussex.
Hawkins, John Isaac, C.E.
*Hawkins, Thomas, F.G.S. The Hermitage, Down Court, Isle of
Wight.
1851. †Hawkins, W. W.
*Hawkshaw, John, F.R.S., F.G.S. 43 Eaton-place, London.
1864. *Hawkshaw, John Clark, B.A., F.G.S. 43 Eaton-place, London.
1853. †Haworth, Benjamin, J.P. Hull Bank House, near Hull.
*Hawthorn, Robert, C.E. Newcastle-upon-Tyne.
1863. †Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. †Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1861. *Hay, Sir John D. United Service Club, London.
1858. †Hay, Samuel. Albion-place, Leeds.
1857. †Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.

Year of
Election.

1856. †Hayward, J. Curtis. Quedgeley, near Gloucester.
 1858. *Hayward, Robert Baldwin, M.A. Harrow-on-the-hill.
 1851. †Head, Jeremiah. Woodbridge-road, Ipswich.
 1865. §Header, William. Torquay.
 1861. *Heald, James. Parr's Wood, Didsbury, near Manchester.
 1863. †Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
 1854. †Healey, Elkanah. Gateacre, Liverpool.
 1861. *Heape, Benjamin. Northwood, near Manchester.
 1854. †Heath, Edward.
 1863. †Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
 Heath, John. 11 Albemarle-street, London.
 1861. §Heathfield, W. E., F.C.S., F.R.G.S. 20 King-street, St. James's,
 London.
 1865. §Heaton, Harry. Warstone, Birmingham.
 1858. *Heaton, John Deakin, M.D. Claremont, Leeds.
 1865. §Heaton, Ralph. Harborne Lodge, near Birmingham.
 1863. †Heckels, Richard. Pensher, near Fencehouses, Durham.
 1855. †Hector, James, M.D., F.R.S.E., F.G.S., F.R.G.S., Geological Survey
 of Otago. New Zealand.
 1863. †Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
 *Heelis, Thomas. Princes-street, Manchester.
 1854. †Heldenmaier, B., Ph.D. Worksop, Notts.
 1862. †Helm, George F. 58 Trumpington-street, Cambridge.
 1857. *Hemans, George William, C.E., M.R.I.A. 32 Leinster-gardens,
 Hyde Park, London.
 1845. †Henderson, Andrew. 120 Gloucester-place, Portman-square, London.
 Henn, Richard. 17 Herbert-street, Dublin.
 1856. †Hennessy, Henry G., F.R.S., M.R.I.A., F.R.G.S. Wynnefield, Rath-
 gar, Co. Dublin.
 1857. †Hennessy, John Pope. Inner Temple, London.
 Henry, Franklin. Portland-street, Manchester.
 Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
 Henry, Mitchell. Stratheden House, Hyde Park, London.
 *Henry, William Charles, M.D., F.R.S., F.R.G.S. Haffield, near Led-
 bury, Herefordshire.
 Henwood, William Jory, F.R.S., F.G.S. 3 Clarence-place, Penzance.
 1855. *Hepburn, J. Gotch. Clapham Common, Surrey.
 1855. †Hepburn, Robert.
 Hepburn, Thomas. Clapham, London.
 Hepworth, John Mason. Ackworth, Yorkshire.
 1856. †Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
 1864. §Herapath, William Bird, M.D., F.R.S. L. & E. Old Market-street,
 Bristol.
 *Herbert, Thomas. Nottingham.
 1852. †Herdman, John. 9 Wellington-place, Belfast.
 Herschel, Sir John Frederick William, Bart., K.H., M.A., D.C.L.,
 F.R.S. L. & E., Hon. M.R.I.A., F.G.S., F.R.A.S. Collingwood,
 near Hawkhurst, Kent.
 1861. †Hertz, James. Sedgley-park, Prestwich, near Manchester.
 1851. †Hervey, The Rev. Lord Arthur. Ickworth, Suffolk.
 1865. §Heslop, Dr. Birmingham.
 1863. †Heslop, Joseph. Pilgrim-street, Newcastle-on-Tyne.
 1832. †Hewitson, William C. Oatlands, Surrey.
 Hey, Rev. William, M.A., F.C.P.S. Clifton, York.
 1861. *Heywood, Arthur Henry. Sedgley-park, Manchester.
 *Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S. 26 Palace-gardens,
 Kensington, London.
 Heywood, Lawrence.

Year of
Election.

1861. *Heywood, Oliver. Acresfield, Manchester.
 *Heywood, Robert. Bolton.
 Heywood, Thomas Percival. Claremont, Manchester.
1854. †Heyworth, Captain L., jun.
1864. *Hiern, W. P., M.A. St. John's College, Cambridge.
1854. *Higgin, Edward. Liverpool.
1861. *Higgin, James. Hopwood-avenue, Manchester.
 Higginbotham, Samuel. Exchange-square, Glasgow.
1861. †Higgins, George. Mount House, Higher Broughton, Manchester.
1854. †Higgins, Rev. Henry H., M.A. Rainhill, Liverpool.
1861. *Higgins, James. Stocks House, Cheetham, Manchester.
1854. †Highley, Samuel, F.G.S. Boxhill, near Dorking, Surrey.
1842. *Higson, Peter. Irwell-terrace, Lower Broughton, Manchester.
 Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsbys, near Grantham,
 Lincolnshire.
1862. *Hiley, Rev. Simeon. St. John's College, Cambridge.
 Hill, Arthur. Bruce Castle, Tottenham.
 *Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1857. †Hill, John. Tullamore, Ireland.
1855. †Hill, Laurence. Port Glasgow.
 *Hill, Sir Rowland, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead,
 London.
1864. §Hill, William. Combe Hay, Bristol.
1863. §Hills, F. C. Chemical Works, Deptford, Kent.
1850. †Hincks, Rev. Edward, D.D. Killyleagh, Ireland.
1858. †Hincks, Rev. Thomas, B.A. Mountside, Leeds.
 Hincks, Rev. William, F.L.S., Professor of Natural History in Uni-
 versity College. Toronto, Canada West.
 Hindley, Rev. H. J. Walton-on-the-hill, Lancashire.
1852. *Hindmarsh, Frederick, F.G.S., F.R.G.S. 17 Bucklersbury, London.
 *Hindmarsh, Luke. Alnwick.
1865. §Hinds, James, M.D. Queen's College, Birmingham.
1863. §Hinds, William, M.D. Parade, Birmingham.
1861. *Himmers, William. Farnworth, Bolton.
1858. §Hirst, John, jun. Dobcross, near Manchester.
1861. *Hirst, Thomas Archer, Ph.D., F.R.S., Professor of Mathematics and
 Physics in University College, London. 14 Waverley-place,
 St. John's-wood, London.
1856. †Hitch, Samuel, M.D. Sandywell Park, Gloucestershire.
1860. †Hitchman, John. Leamington.
 *Hoare, Rev. George Tooker. Tandridge, Godstone.
 Hoare, J. Gurney. Hampstead, London.
1864. †Hobhouse, Arthur Fane. 24 Cadogan-place, Sloane-street, London.
1864. †Hobhouse, Charles Parry. 24 Cadogan-place, Sloane-street, London.
1864. †Hobhouse, Henry William. 24 Cadogan-place, Sloane-street, London.
1863. §Hobson, A. S., F.C.S. 3 Upper Heathfield-terrace, Turnham Green,
 London.
1852. †Hodges, John F., M.D., Professor of Agriculture in Queen's College,
 Belfast. 23 Queen-street, Belfast.
 *Hodgkin, Thomas, M.D., F.R.G.S. 35 Bedford-square, London.
1863. *Hodgkin, Thomas. (*Local Treasurer.*) Newcastle-on-Tyne.
1847. †Hodgkinson, Rev. G. C. The Lodge, Louth.
 *Hodgson, Adam. Everton, Liverpool.
 Hodgson, Joseph, F.R.S. 60 Westbourne-terrace, London.
1863. §Hodgson, Robert. Whitburn, Sunderland.
1863. †Hodgson, R. W. North Dene, Gateshead.
 Hodgson, Thomas. Market-street, York.
1860. †Hogan, Rev. A. R., M.A. Puddletown, Dorchester.

Year
Election.

1865. §Hofmann, Augustus William, F.R.S., F.C.S. Chemical Laboratory of the University of Berlin.
Hogán, William, M.A., M.R.I.A. Haddington-terrace, Kingstown, near Dublin.
Hogg, John, M.A., F.R.S., F.L.S., F.R.G.S., F.C.P.S. 8 Serjeants' Inn, London; and Norton, Stockton-on-Tees.
1861. †Holcroft, George, C.E. Red Lion-court, St. Ann's-square, Manchester.
1854. †Holcroft, George. 82 Great Ducie-street, Manchester.
*Holditch, Rev. Hamnet, M.A. Caius College, Cambridge.
1856. †Holland, Henry, M.P. Dumbleton, Evesham.
1858. †Holland, Loton. Swanscoe Park, Macclesfield.
*Holland, P. H.
1865. §Holliday, William. New Street, Birmingham.
*Hollingsworth, John. London-street, Greenwich, Kent.
Holmes, Rev. W. R.
Holt, Edward.
Holt, Henry. Notton, near Wakefield.
Hone, Joseph, M.R.D.S. 2 Harcourt-street, Dublin.
*Hone, Nathaniel, M.R.I.A. Doloughs Park, Co. Dublin.
1851. †Honywood, Robert.
1858. †Hook, The Very Rev. W. F., D.D., Dean of Chichester. Chichester.
1847. †Hooker, Joseph D., M.D., D.C.L., F.R.S., V.P.L.S., F.G.S. Royal Gardens, Kew.
1865. *Hooper, John P. Fremerton House, Balham, London.
1861. §Hooper, William. 7 Pall Mall East, London.
1856. †Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Liverpool.
Hope, William. Wavertree, Liverpool.
1865. §Hopkins, J. S. Highfield, Edgbaston, Birmingham.
*Hopkins, William, M.A., LL.D., F.R.S., F.G.S. Cambridge.
1858. †Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hopkinson, William. Stamford.
Hornby, Hugh. Sandown, Liverpool.
1864. *Horner, Rev. J. J. H. Mells Rectory, Frome.
1858. *Horsfall, Abraham. Leeds.
Horsfall, Charles. Everton, Liverpool.
Horsfall, John. Wakefield.
1854. †Horsfall, Thomas B., M.P. Liverpool.
1855. *Horsfield, George. Brampton-grove, Smedley-lane, Cheetham, Manchester.
1856. †Horsley, John H. 389 High-street, Cheltenham.
Hotham, Rev. Charles, M.A., F.L.S. Roos Patrington, Yorkshire.
1859. §Hough, Joseph. Wrottesley, near Wolverhampton.
Houghton, The Right Hon. Lord. 16 Upper Brook-street, London.
Houghton, James. Rodney-street, Liverpool.
Houghton, William.
1842. *Houldsworth, Henry. Newton-street, Manchester.
1858. †Hounsfield, James. Hemsworth, Pontefract.
1842. †Houtson, John.
Hovenden, W. F., M.A. Bath.
1859. †Howard, Captain John Henry, R.N. The Deanery, Lichfield.
1863. †Howard, Philip Henry. Corby Castle, Carlisle.
1857. †Howell, Henry H. Museum of Practical Geology, Jermyn-street, London.
1865. *Howlett, Rev. Frederick, F.R.S. St. Augustine's, Hurst-green, Sussex.

Year of
Election.

1863. §Howorth, H. H. Castleton Hall, Rochdale.
 1863. †Howse, R. South Shields.
 1854. †Howson, Rev. J. S. South-hill, Toxteth Park, Liverpool.
 Hudson, George.
 *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
 Hudson, John. Oxford.
 1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London.
 1858. †Huggins, William, F.R.A.S. Upper Tulse-hill, London.
 1857. §Huggon, William. 30 Park-row, Leeds.
 Hughes, D. Abraham. 9 Grays Inn-square, London.
 Hughes, Frederick Robert.
 Hughes, H. H.
 1863. §Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.
 1865. §Hughes, W. R., F.L.S. General Hospital, Birmingham.
 Hull, Arthur H. Brighton.
 *Hull, William Darley, F.G.S.
 Hulley, Dr.
 *Hulse, Sir Edward, D.C.L. 4 New Burlington-street, London; and
 Breamore House, Salisbury.
 1861. †Hume, Rev. A., D.C.L., F.S.A. Everton, Liverpool.
 1845. †Humpage, Edward. Bristol.
 1856. †Humphreys, E. R., LL.D.
 1856. †Humphries, David James. 1 Keynsham-parade, Cheltenham.
 1862. *Humphry, George Murray, M.D., F.R.S. Trumpington-street, Cambridge.
 1863. *Hunt, Augustus H., Ph.D. Pelaw Main Office, Newcastle-on-Tyne.
 1860. †Hunt, James, Ph.D., F.S.A. Ore House, Hastings.
 1865. §Hunt, J. P. Congreaves, Birmingham.
 1840. §Hunt, Robert, F.R.S., Keeper of the Mining Records. Museum of
 Practical Geology, Jermyn-street, London.
 1864. †Hunt, W. 72 Pulteney-street, Bath.
 Hunter, Adam, M.D., F.R.S.E. Edinburgh.
 Hunter, Andrew G. Low Walker, Newcastle-on-Tyne.
 Hunter, Robert, F.R.S., F.G.S., F.R.A.S., F.S.A. Southwood-
 lane, Highgate, London.
 1859. †Hunter, Dr. Thomas, Deputy Inspector-General of Army Hospitals.
 1855. *Hunter, Thomas C. Greenock.
 1863. §Huntsman, Benjamin. West Retford Hall, Retford.
 1861. *Hurst, William John. 2A Victoria-street, Manchester.
 1851. †Hurwood, George.
 Husband, William Dalla. Coney-street, York.
 *Hutchinson, John. Widnes Dock, Warrington.
 1863. †Hutt, The Right Hon. W., M.P. Gibside, Gateshead.
 Hutton, Crompton. Putney-park, Surrey.
 Hutton, Daniel. 4 Lower Dominick-street, Dublin.
 1864. *Hutton, Darnton. 11 Warnford-court, Throgmorton-street, London.
 Hutton, Edward, M.D., M.R.I.A. 29 Gardiner's-place, Dublin.
 Hutton, Henry. Eccles-street, Dublin.
 1857. †Hutton, Henry D. 1 Nelson-street, Dublin.
 *Hutton, Robert, M.R.I.A., F.G.S. Putney Park, Surrey.
 1861. §Hutton, T. Maxwell. Summerhill, Dublin.
 1852. †Huxley, Thomas Henry, Ph.D., F.R.S., F.L.S., F.G.S., Professor of
 Natural History in the Government School of Mines, and Hun-
 terian Professor of Comparative Anatomy in the Royal College
 London.
 1846. †Huxtable, Rev. Anthony. Sutton Waldron, near Blandford.

Year of
Election.

- Hyde, Edward. Dukinfield, near Manchester.
Hyett, William Henry, F.R.S. Painswick, near Stroud, Gloucestershire.
1847. †Hyndman, George C. 5 Howard-street, Belfast.
- *Ibbetson, Captain L. L. Boscawen, Chevalier Red Eagle of Prussia
with Swords, Chevalier de Hohenzollern, F.R.S., F.G.S.
1854. †Ihne, William, Ph.D.
1861. †Iles, Rev. J. H. Rectory, Wolverhampton.
1858. †Ingham, Henry. Wortley, near Leeds.
1858. †Ingram, Hugo C. Meynell. Temple Newsam, near Leeds.
1858. *Ingram, Hugo Francis Meynell. Temple Newsam, Leeds.
1852. †Ingram, J. K., LL.D., M.R.I.A., Professor of Oratory. Trinity College, Dublin.
1854. *Inman, Thomas, M.D. Rodney-street, Liverpool.
1856. †Invararity, J. D. Bombay.
Ireland, R. S., M.D. 121 Stephen's Green, Dublin.
1857. †Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
Irwin, Rev. Alexander, M.A. Armagh, Ireland.
1845. †Irwin, Thomas. Somerset House, London.
1862. §Iselin, J. F., M.A. Wimbledon, Surrey.
1863. *Ivory, Thomas. 9 Ainslie-place, Edinburgh.
1865. §Jabet, George. Wellington-road, Handsworth, Birmingham.
1859. §Jack, John. Belhelvie by White Cairns, Aberdeenshire.
1863. *Jackson, Mrs. H. 24 Hereford-square, Gloucester-road, Old Brompton, London.
1865. §Jackson, Edwin. Southport, Lancashire.
1858. †Jackson, Edwin W.
Jackson, Professor Thomas, LL.D. St. Andrew's, Scotland.
1855. †Jackson, Rev. William, M.A. St. John's, Workington.
Jacob, Arthur, M.D. 23 Ely-place, Dublin.
1852. †Jacobs, Bethel. 40 George-street, Hull.
1865. *Jaffray, John. 'Journal' Office, New-street, Birmingham.
1859. †James, Edward. 9 Gascoyne-terrace, Plymouth.
1860. †James, Edward H. 9 Gascoyne-terrace, Plymouth.
James, Colonel Sir Henry, R.E., F.R.S., F.G.S., M.R.I.A. Ordnance Survey Office, Southampton.
James, Sir John K., M.R.I.A., Bart. 9 Cavendish-row, Dublin.
1863. *James, Sir Walter. 6 Whitehall-gardens, London.
1858. †James, William C. 9 Gascoyne-terrace, Plymouth.
1863. †Jameson, John Henry. 10 Catherine-terrace, Gateshead.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. †Jardine, Alexander. Jardine Hall, Lockerby.
Jardine, James, C.E., F.R.A.S. Edinburgh.
*Jardine, Sir William, Bart., F.R.S.E. Jardine Hall, Applegarth by Lockerby, Dumfriesshire.
1853. *Jarratt, Rev. John, M.A. North Cave, near Brough, Yorkshire.
Jarrett, Rev. Thomas, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1862. §Jeakes, Rev. James, M.A. Harrow.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1842. *Jee, Alfred S. 2 Oxford-square, Hyde Park, London.
1856. †Jeffery, Henry, M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. 193 St. Vincent-street, Glasgow.
1861. *Jeffreys, J. Gwyn, F.R.S., F.L.S., F.G.S. 25 Devonshire-place, Portland-place, London.
Jeffreys, Rev. R., B.D. Cockfield, Suffolk.

Year of
Election.

1854. †Jeffreys, W. P. Washington-street, Liverpool.
 1852. †Jellett, Rev. John H., M.A., M.R.I.A. Trinity College, Dublin.
 1842. Jellicorse, John. Chaseley, near Rugely, Staffordshire.
 1864. §Jelly, Dr. W. Paston Hall, near Peterborough.
 1862. §Jenkin, Fleeming, F.R.S. 6 Duke-street, Adelphi, London.
 1864. §Jenkins, Captain Griffith, C.B., F.R.G.S. Derwin, Welshpool.
 *Jenkyns, Rev. Henry, D.D. Durham.
 Jennette, Matthew. Birkenhead.
 1852. †Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
 1861. †Jennings, Thomas. Cork.
 *Jenyns, Rev. Leonard, M.A., F.L.S., F.G.S. 1 Darlington-place, Bathwick, Bath.
 1845. †Jerdan, William.
 *Jerram, Rev. S. John, M.A. Chobham Vicarage, Bagshot, Surrey.
 *Jerrard, George Birch, B.A. Long Stratton, Norfolk.
 1845. †Jessop, William, sen. Butterley Hall, Derbyshire.
 Jessop, William, jun. Butterley Hall, Derbyshire.
 1849. †Jeune, The Right Rev. Francis, D.C.L., Bishop of Peterborough.
 Job, Samuel. Holmfield House, Aigburth, Liverpool.
 1865. *Johnson, G. J. 34 Waterloo-street, Birmingham.
 1861. †Johnson, Richard. 27 Dale-street, Manchester.
 1863. †Johnson, R. S. Hanwell, Fence Houses, Durham.
 *Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
 1864. §Johnson, Thomas.
 Johnson, William. The Wynds Point, Colwall, Malvern, Worcester-shire.
 1861. †Johnson, William Beckett. Woodlands Bank, near Altrincham.
 1849. §Johnston, Alexander Keith, LL.D., F.R.S.E., F.G.S., F.R.G.S. 4 St. Andrew-square, Edinburgh.
 Johnston, Alexander Robert, F.R.S. 19 Cumberland-place, London ; and York House, Twickenham.
 1859. †Johnston, David, M.D. Montrose.
 1864. †Johnston, David. 13 Marlborough-buildings, Bath.
 Johnston, Edward. Field House, Chester.
 1845. †Johnston, G., M.D.
 1859. †Johnston, James. Newmill, Elgin, N. B.
 1864. †Johnston, James. Manor House, Northend, Hampstead, London.
 Johnston, Percival Norton, F.R.S., F.G.S. Stoke House, Stoke Fleming, Dartmouth.
 *Johnstone, James. Alva, near Alloa, Stirlingshire.
 *Johnstone, Sir John Vanden Bempde, Bart., M.P., M.A., F.G.S. 27 Grosvenor-square, London ; and Harkness.
 1864. †Johnstone, John. 1 Barnard-villas, Bath.
 Jollie, Walter. Edinburgh.
 1864. †Jolly, Thomas. Park View-villas, Bath.
 1849. †Jones, Baynham. Selkirk Villa, Cheltenham.
 *Jones, Christopher Hird. 2 Castle-street, Liverpool.
 1856. †Jones, C. W. 7 Grosvenor-place, Cheltenham.
 *Jones, Major Edward.
 Jones, Rev. Harry Longueville, Inspector of Schools.
 1858. †Jones, Henry Bence, M.A., M.D., F.R.S., Hon. Sec. to the Royal Institution. 31 Brook-street, Grosvenor-square, London.
 1854. †Jones, Rev. Henry H. Cemetery, Manchester.
 1854. †Jones, John. 28 Chapel-street, Liverpool.
 1864. §Jones, John, F.G.S. The Trindle, Dudley.
 1865. §Jones, John. 49 Union-passage, Birmingham.
 *Jones, Josiah. 2 Castle-street, Liverpool.

Year of
Election.

- *Jones, Robert. 2 Castle-street, Liverpool.
1854. *Jones, R. L. Princes Park, Liverpool.
1847. †Jones, Thomas Rymer, Professor of Comparative Anatomy in King's College. 18 St. Leonard's-terrace, Clifton-gardens, Maida-hill, London.
1860. §Jones, T. Rupert, F.G.S., Professor of Geology and Mineralogy, Royal Military Academy, Sandhurst, near Farnborough.
1850. †Jones, William.
1864. §Jones, Sir Willoughby. Cranmer Hall, Feckenham, Norfolk.
1853. †Jopling, R. Thompson.
1851. †Josselyn, G. Tower-street, Ipswich.
- *Joule, Benjamin St. John B. Thorncliffe, Old Trafford, Manchester.
1842. *Joule, James Prescott, LL.D., F.R.S., F.C.S. Thorncliffe, Old Trafford, Manchester.
- *Joy, Rev. Charles Ashfield. Grove Parsonage, near Wantage, Berkshire.
- Joy, Henry Holmes, M.A., M.R.I.A. 17 Mountjoy-square East, Dublin.
- Joy, Rev. J. H.
- Joy, William B., M.D. 48 Leeson-street, Dublin.
1847. †Jowett, Rev. B., M.A. Balliol College, Oxford.
1858. †Jowett, John, jun. Leeds.
- *Jubb, Abraham. Halifax.
1863. §Jukes, Rev. Andrew. Spring Bank, Hull.
- Jukes, Joseph Beete, M.A., F.R.S., F.G.S., M.R.I.A., Local Director of the Government Geological Survey of Ireland. 51 Stephen's Green, Dublin.
- Kane, Sir Robert, M.D., F.R.S., M.R.I.A., Principal of the Royal College of Cork. 51 Stephen's Green, Dublin.
1857. †Kavanagh, James W. Grenville, Rathgar, Ireland.
1859. †Kay, David, F.R.G.S. 6 North-bridge, Edinburgh.
- Kay, John Cunliff. Fairfield Hall, near Skipton.
- *Kay, John Robinson. Boss Lane House, Bury, Lancashire.
- Kay, Robert. Haugh Bank, Bolton-le-Moors.
1847. *Kay, Rev. William, D.D. Lincoln College, Oxford.
1856. †Kay-Shuttleworth, Sir James, Bart. Gawthorpe, Burnley.
1855. †Kaye, Robert. Mill Brae, Moodies Burn, by Glasgow.
1855. †Keddie, William. 15 North-street, Mungo-street, Glasgow.
1850. †Kelland, Rev. Philip, M.A., F.R.S.L. & E., Professor of Mathematics in the University of Edinburgh. 20 Clarendon Crescent, Edinburgh.
1849. †Kelly, John, C.E. 38 Mount Pleasant-square, Dublin.
1857. †Kelly, John J. 38 Mount Pleasant-square, Dublin.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1842. *Kelsall, Henry. Rochdale, Lancashire.
1842. Kelsall, J. Rochdale, Lancashire.
1864. *Kemble, Rev. Charles, M.A. Vellore, Bath.
1853. †Kemp, Rev. Henry William, B.A. Thanet House, Hull.
1858. †Kemplay, Christopher. Leeds.
1850. †Kempson, Samuel.
1857. †Kennedy, George A., M.D., M.R.I.A.
1854. †Kennedy, James. 33 Erskine-street, Liverpool.
1857. †Kennedy, Lieut-Colonel John Pitt. 20 Torrington-square, Bloomsbury, London.
1858. †Kennie, C. G. Colleton. 5A Spring-gardens, London.
- Kenny, Matthias, M.D. 3 Clifton-terrace, Monkstown, Co. Dublin.

Year of
Election.

Kenrick, Rev. George.

1865. §Kenrick, William. Norfolk-road, Edgbaston, Birmingham.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. †Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. †Kenworth, James Ryley. 7 Pembroke-place, Liverpool.
1857. *Ker, André Allen Murray. 7 Trafalgar-terrace, Monkstown,
Dublin.
1855. *Ker, Robert. Auchinraith, Glasgow.
Ker, Stewart.
1865. *Kerr, William D., M.D., R.N. Bennyrigg, Edinburgh.
1861. *Keymer, John. Parker-street, Manchester.
1854. †Kilpin, Thomas Johnstone. 1 Arrad-street, Liverpool.
1865. *Kinahan, Edwin Hudson. 11 Merrion-square North, Dublin.
1860. †Kinahan, G. Henry. Geological Survey of Ireland, 51 Stephen's
Green, Dublin.
1858. †Kincaid, Henry Ellis, M.A. 8 Lyddon-terrace, Leeds.
1854. †King, Alfred. 1 Netherfield-road South, Liverpool.
1855. †King, Alfred, jun. Everton, Liverpool.
King, The Hon. James, M.R.I.A. Mitchelstown Castle, Co. Cork.
1855. †King, James. Leverholme, Hurlet, Glasgow.
1851. †King, John. Ipswich.
1851. †King, John. Rose-hill, Ipswich.
King, Joseph. Anfield-road, Liverpool.
1864. §King, Kelburne. 27 George Street; and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. 1 Rodney-place, Clifton, Bristol.
1842. King, Richard, M.D. Savile-row, London.
King, Rev. Samuel, M.A., F.R.A.S. St. Aubins, Jersey.
1862. §King, Rev. Samuel William, F.G.S., F.S.A. Saxlingham Rectory,
near Norwich.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1862. †Kingsley, Rev. Charles, M.A., Professor of Modern History in the
University of Cambridge. 1 St. Peter's-terrace, Cambridge.
1861. †Kingsley, John. 30 St. Ann's-street, Manchester.
1845. †Kingsley, Rev. W. T. South Kelvington, Thirsk.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1863. §Kinnaird, The Right Hon. Lord., F.G.S. Rossie Priory, Inchtute.
Kinneir, J. G., F.R.S.E. Glasgow.
1863. †Kirkaldy, David. 28 Bartholemew-road North, Kentish Town,
London.
1860. §Kirkman, Rev. Thomas P., M.A., F.R.S. Croft Rectory, near War-
rington.
Kirkpatrick, Rev. W. B. 44 Wellington-street, Dublin.
1850. §Kirkwood, Anderson. 151 West George-street, Glasgow.
Kirshaw, James.
1849. †Kirshaw, John William, F.G.S. Warwick.
1858. †Kitson, James. Leeds.
Knight, Sir A. J., M.D.
Knipe, A. J. Moorville, Carlisle.
Knowles, George Beauchamp, Professor of Botany in Queen's College,
Birmingham. St. Paul's-square, Birmingham.
1842. Knowles, John. Old Trafford Bank House, Old Trafford, Manchester.
Knowles, L. P.
*Knowles, William. 2 Clarence-place, Newport, Monmouthshire.
- *Knox, G. James. 2 Finchley New-road, St. John's-wood, London.
Knox, Henry.
Knox, Rev. H. B., M.A., M.R.I.A. Deanery, Hadleigh, Suffolk.
Kutz, Andrew.
1861. *Kyllmann, Max. 28 Brazennose-street, Manchester,

Year of
Election.

1865. §Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.
 Lace, Ambrose. Liverpool.
 1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
 1862. §Lackenstien, Dr. (Care of Messrs. Smith and Elder, Cornhill, London.)
 1842. Lacy, Henry C. Withdeane Hall, near Brighton.
 1859. §Ladd, William. 11 & 13 Beak-street, Regent-street, London.
 1850. †Laing, David, F.S.A. Scotl. Edinburgh.
 Laird, John, M.P. Birkenhead.
 1859. §Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
 Lamb, David. Liverpool.
 Lambert, Richard. Newcastle-on-Tyne.
 1846. *Laming, Richard. 10 Clifton Villas, Maida-hill West, London.
 1854. §Lamport, William James. Liverpool.
 1859. †Lang, Rev. John Marshall. Fyvie, Aberdeen.
 1864. §Lang, R. Burlington Bogs, Redlands, Bristol.
 *Langton, William. Manchester.
 1840. †Lankester, Edwin, M.D., LL.D., F.R.S., F.L.S. 8 Savile-row, London.
 1865. §Lankester, E. Ray. Downing College, Cambridge.
 *Larcom, Major-General Sir Thomas Aiskew, K.C.B., R.E., F.R.S., M.R.I.A. Phoenix Park, Dublin.
 Lassell, William, F.R.S., F.R.A.S. Malta.
 1860. †Lassell, William, jun. The Brook, near Liverpool.
 1861. *Latham, A. G. Cross-street, Manchester.
 1845. †Latham, Robert G., M.A., M.D., F.R.S., F.R.G.S. New Malden, near Kingston, Surrey.
 *La Touche, David Charles, M.R.I.A. Castle-street, Dublin.
 1857. †Law, Hugh. 4 Great Denmark-street, Dublin.
 1862. †Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
 Law, Rev. William, M.A. Orwell Rectory, Arrington.
 Lawley, The Hon. Francis Charles. Escrick Park, near York.
 Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
 Lawrence, William, F.R.S., Serjeant-Surgeon to the Queen. 18 Whitehall-place, London.
 1857. †Lawson, James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
 1855. †Lawson, John. Mountain Blue Works, Camlachie.
 1858. †Lawson, Samuel. Kirkstall, near Leeds.
 1863. §Lawton, Benjamin C. Tynemouth.
 1853. †Lawton, William. Manor House-street, Hull.
 Laycock, Thomas, M.D., Professor of the Practice of Medicine in the University of Edinburgh. 4 Rutland-street, Edinburgh.
 1865. §Lea, Henry. 35 Paradise-street, Birmingham.
 1857. †Leach, Capt. R. E. Mountjoy, Phoenix Park, Dublin.
 Leadbetter, John. Glasgow.
 1847. *Leatham, Edward Aldam. Whitley Hall, Huddersfield.
 1858. †Leather, George. Knostrop, near Leeds.
 *Leather, John Towlerton. Leventhorpe Hall, near Leeds.
 1858. †Leather, John W. Newton Green, Leeds.
 1863. §Leavers, J. W. The Park, Nottingham.
 1858. *Le Cappelain, John. Wood-lane, Highgate, London.
 1858. †Ledgard, William. Potter Newton, near Leeds.
 1842. Lee, Daniel. Springfield House, Pendlebury, Manchester.
 1861. §Lee, Henry. Irwell House, Lower Broughton, Manchester.
 Lee, Henry, M.D. Weatheroak, Alve Church, near Bromsgrove, London.

Year of
Election.

1853. *Lee, John Edward, F.G.S., F.S.A. The Priory, Caerleon, Monmouthshire.
1845. †Lees, Dr. Frederick R. Burmantofts Hall, Leeds.
1850. †Lees, George, LL.D. Rillbank, Edinburgh.
1854. †Lees, Samuel. Portland-place, Ashton-under-Lyne.
1859. †Lees, William. School of Art, Edinburgh.
- *Leese, Joseph, jun. Glenfield, Altrincham.
- *Leeson, Henry B., M.A., M.D., F.R.S. The Maples, Bonchurch, Isle of Wight.
- *Lefroy, John Henry, Brigadier-General R.A., F.R.S., F.R.G.S., President of the Ordnance Select Committee. Blackheath, Kent.
1845. †Legard, Capt. William. India.
- *Legh, George Cornwall, M.P. High Legh, Cheshire.
- Legh, Peter Thomas.*
1856. §Leigh, The Right Hon. Lord. Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. The Poplars, Patricroft, near Manchester.
- Leigh, John Shaw. Childerall Hall, near Liverpool.
- *Leinster, Augustus Frederick, Duke of, M.R.I.A. 6 Carlton House-terrace, London.
1859. †Leith, Alexander. Glenkindie, Inverkindie.
- *Lemon, Sir Charles, Bart., F.R.S., F.G.S., F.R.G.S. Carclew, near Falmouth.
1860. †Lempriere, Charles, D.C.L. St. John's College, Oxford.
1863. *Lendy, Capt. Augusta Frederic. Practical Military College, Sunbury.
1861. †Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London.
- Lentaigne, John, M.D. Tallaght House, Co. Dublin; and 14 Great Dominick-street, Dublin.
- Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1861. †Leppoc, Henry Julius. Kersal Crag, near Manchester.
1852. †Leslie, T. E. Cliffe, LL.B.
1859. †Leslie, William, M.P. Warthill, Aberdeenshire.
1846. †Letheby, Henry, M.B., F.L.S., Medical Officer to the City of London. 41 Finsbury-square, London.
1847. †Ley, Rev. Jacob, M.A. Staverton, near Daventry.
1853. †Liddell, George William Moore. Sutton House, near Hull.
1860. †Liddell, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1855. †Liddell, John. 8 Clelland-street, Glasgow.
1859. †Ligertwood, George. Blair by Summerhill, Aberdeen.
1864. §Lightbody, Robert, F.G.S. Ludlow, Salop.
- Lightfoot, J. J.*
1862. †Lilford, Right Hon. Lord. Lilford Hall, Northamptonshire.
- *Lindsay, Charles. Glen Osmond, Adelaide, South Australia.
- *Lindsay, Henry L., C.E., M.R.I.A. 1 Little Collins-street West, Montreal, Canada.
1855. *Lindsay, John H. 317 Bath-street, Glasgow.
1842. *Lingard, John R., F.G.S. Stockport, Cheshire.
- Lingwood, Robert M., M.A., F.L.S., F.G.S.*
- Lister, James. Liverpool Union Bank, Liverpool; and Greenbank, Everton.
1858. *Lister, John, F.G.S. Shibden Hall, near Halifax.
- *Lister, Joseph Jackson, F.R.S. Upton, Essex.
- Littledale, Harold. Liscard Hall, Cheshire.
1854. †Littledale, Thomas. Highfield House, Liverpool.
1861. *Liveing, G. D., M.A., F.C.S., Professor of Chemistry in the University of Cambridge. 12 Hill's-road, Cambridge.
1864. §Livesay, J. G. Ventnor, Isle of Wight.
1860. †Livingstone, Rev. Thomas Gott, Minor Canon of Carlisle Cathedral.
- Lloyd, Rev. A. R. Hengold, near Oswestry.

Year of
Election.

- Lloyd, Rev. C., M.A. Whittington, Oswestry.
 1848. †Lloyd, Rev. David. Carmarthen.
 1842. Lloyd, Edward. King-street, Manchester.
 1854. †Lloyd, F. Geisler.
 1847. *Lloyd, George Whitelocke.
 1865. §Lloyd, G. B. Wellington-road, Edgbaston, Birmingham.
 *Lloyd, George, M.D., F.G.S. Birmingham.
 *Lloyd, Rev. Humphrey, D.D., LL.D., F.R.S. L. & E., M.R.I.A.
 Trinity College, Dublin.
 1865. §Lloyd, John. Queen's College, Birmingham.
 Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
 1849. †Lloyd, William, M.D. Army and Navy Club, London.
 1865. *Lloyd, Wilson. Wood Green, Wednesbury, Wolverhampton.
 1854. *Lobley, James Logan, F.G.S. 50 Landsdowne-road, Kensington
 Park, London.
 1853. *Locke, John. Royal Dublin Society, Kildare-street, Dublin.
 *Lockey, Rev. Francis. Swainswick, near Bath.
 Lockhart, Alexander M'Donald.
 1863. §Lockyer, J. Norman, F.R.A.S. Victoria-road, Finchley-road, Lon-
 don.
 1853. †Loft, John. 17 Albion-street, Hull.
 *Loftus, William Kennett, F.G.S. Calcutta.
 *Logan, Sir William Edmond, LL.D., F.R.S., F.G.S., F.R.G.S., Di-
 rector of the Geological Survey of Canada. Montreal, Canada.
 1864. †Logan, Edmund. 141 George-street, Edinburgh.
 1862. †Long, Andrew, M.A. King's College, Cambridge.
 1851. †Long, P. B. Museum-street, Ipswich.
 1851. †Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
 1857. †Longfield, Rev. George. 25 Trinity College, Dublin.
 Longfield, Mountifort, LL.D., M.R.I.A., Regius Professor of Feudal
 and English Law in the University of Dublin. 47 Fitzwilliam-
 square, Dublin.
 1861. *Longman, William, F.G.S. 36 Hyde Park-square, London.
 1859. †Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
 Longridge, W. S. Oakhurst, Ambergate, Derbyshire.
 1865. §Longsdon, Robert. Church House, Bromley, Kent.
 1861. *Lord, Edward. York-street, Todmorden.
 1855. †Lorimer, Rev. J. G., D.D. 6 Woodside-place, Glasgow.
 1863. †Losh, W. S. Wreay Syke, Carlisle.
 1834. †Low, Rev. Alexander, F.S.A.
 1863. *Lowe, Arthur S. H. Gosfield Hall, near Nottingham.
 1861. *Lowe, Edward Joseph, F.R.A.S., F.L.S., F.G.S. Ilighfield House
 Observatory, near Nottingham.
 Lowe, George, F.R.S., F.G.S., F.R.A.S. 9 St. John's-wood Park,
 London.
 1850. †Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edin-
 burgh.
 Lowndes, Matthew D. 49 Edge-lane, near Liverpool.
 Lowndes, W.
 1853. *Lubbock, Sir John, Bart., F.R.S., F.L.S., F.G.S. Lamas, Chislehurst,
 Kent.
 Lucena, James L. 4 Garden-court, Temple, London.
 1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
 1849. †Lucy, William. Edgbaston, Birmingham.
 1850. *Landie, Cornelius. Rhymney Railway, Cardiff.
 1853. †Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
 1858. *Lupton, Arthur. Newton Hall, Leeds.
 1864. *Lupton, D. Leeds.

Year of
Election.

- **Lutwidge, Charles, M.A.*
Lutwidge, R. W. S., M.A., F.C.P.S.
 *Lyell, Sir Charles, Bart., M.A., LL.D., D.C.L., F.R.S., F.L.S.,
 V.P.G.S., Hon. M.R.S.Ed. 53 Harley-street, Cavendish-square,
 London.
1864. †Lyne, Francis. (Care of Sydney Smith, Esq., Charlotte-row, Mansion
 House, London.)
1857. †Lyons, Robert D. 31 Upper Merrion-street, Dublin.
1862. *Lyte, Maxwell F., F.C.S. Bagnères de Bigorre, France.
1849. †Lyttelton, The Right Hon. Lord. 17 St. James's-place, London.
1859. †Mabson, John. Trinity College, Cambridge; and Heyning, West-
 moreland.
1852. †MacAdam, James, jun. Beavor Hall, Belfast.
1852. †MacAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry.
 Surgeons' Hall, Edinburgh.
1852. †*Macaldin, J. J., M.D. Coleraine.*
 *M'All, Rev. Edward, Rector of Brighstone, Newport, Isle of
 Wight.
- *M'Andrew, Robert, F.R.S. Isleworth House, Isleworth, Middlesex.
1855. †*M'Arthur, Richard, W. J.*
1840. Macaulay, Dr. James. 23 Pelham-street, Brompton, London.
1857. †*Macaulay, James William.*
 *MacBrayne, Robert. Messrs. Black and Wingate, 9 Exchange-
 square, Glasgow.
 Macbride, Rev. John David, D.C.L., F.G.S., Principal of Magdalen
 Hall, and Lord Almoner's Reader in Arabic in the University
 of Oxford. Oxford.
1855. †M'Callum, Archibald K., M.A. House of Refuge, Duke-street,
 Glasgow.
1863. †M'Calmont, Robert. Gatton Park, Reigate.
1855. †M'Cann, James, F.G.S. Holmfrith, Yorkshire.
1857. †M'Causland, Dominick. 12 Fitzgibbon-street, Dublin.
 M'Clelland, James. 73 Kensington Gardens-square, Bayswater.
1855. †M'Clelland, James. 10 Claremont-terrace, Glasgow.
1856. †*M'Clelland, John. Calcutta.*
 *M'Connell, James. Bent-hill, Prestwich, near Manchester.
1859. **M'Connell, David C., F.G.S.*
1858. †M'Connell, J. E. Woodlands, Great Missenden.
1852. †M'Cosh, Rev. James, M.A., Professor of Logic, &c., Queen's College,
 Belfast.
1851. †M'Coy, Professor Frederick, F.G.S., Professor of Zoology and Natural
 History in the University of Melbourne, Australia.
M'Cullagh, John, A. B.
 *M'Culloch, George, M.D. Cincinnati, United States.
1852. †M'Dermott, Edward. Grove Park, The Grove, Camberwell, Lon-
 don.
1850. †*Macdonald, Alexander.*
 Macdonald, William, M.D., F.R.S.E., F.L.S., F.G.S., Professor of
 Civil and Natural History. St. Andrews, N. B.
 MacDonnell, Hercules H. G. Provost's House, Trinity College, Dublin.
1864. †MacDonnell, The Very Rev. Canon. 8 Montpellier, Bath.
 *MacDonnell, Rev. Richard, D.D., Provost of Trinity College, Dublin,
 M.R.I.A. Dublin.
 Macdougall, A. H. 44 Parliament-street, London.
- *M'Ewan, John. Glasgow.
1850. †Macfarlan, John Fletcher. Park-place, Edinburgh.

Year of
Election.

1859. †Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
 1855. †M^cFarlane, Walter. Saracen Foundry, Glasgow.
 1854. *Macfie, R. A. 72 Upper Parliament-street, Liverpool.
 1852. *M^cGee, William, M.D. 10 Donegal-square East, Belfast.
 1855. †MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
 MacGregor, Alexander.
 1855. †M^cGregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
 1855. †MacGregor, James Watt. Wallace-grove, Glasgow.
 1850. †M^cGregor, Robert, M.D. Glasgow.
 1853. †M^cGregor, Walter. Liverpool.
 1854. †Macgregor, William.
 1859. †M^cHardy, David. 54 Netherkinkgate, Aberdeen.
 1854. †M^cIleen, Alexander Sinclair.
 1855. †M^cIlwraith, H. Greenock.
 Macintosh, General Alexander Fisher, K.H., F.G.S., F.R.G.S.
 7 Tilney-street, Park-lane, London.
 1859. †Macintosh, John. Middlefield House, Woodside, Aberdeen.
 1854. *MacIver, Charles. Abercrombie-square, Liverpool.
 1865. §Mackeson, H. B. Hyde, Kent.
 1865. §Mackintosh, Daniel, F.G.S. Chichester.
 M^cKenney, John.
 1855. †M^cKenzie, Alexander. 89 Buchanan-street, Glasgow.
 *Mackenzie, James. Glentore, Scotland.
 1850. †Mackenzie, J. W. 16 Royal Circus, Edinburgh.
 Mackenzie, Rev. Kenneth. The Manse, Borrowstoness, Linlithgowshire.
 1865. §Mackenzie, Kenneth Robert Henderson. Orford House, Cheswick.
 Mackerral, William. Paisley.
 1859. †Mackie, David. Mitchell-place, Aberdeen.
 *Mackinlay, David. Pollokshields, Glasgow.
 1865. §Mackray, John.
 1850. †Maclagan, Douglas, M.D., F.R.S.E. 28 Heriot Row, Edinburgh.
 1860. †Maclaren, Archibald. Summertown, Oxfordshire.
 1845. §MacLaren, Charles, F.R.S.E. Moreland Cottage, Grange Loan,
 Edinburgh.
 1864. §MacLaren, Duncan, M.P. Newington House, Edinburgh.
 1855. †MacLaren, John.
 1865. *M^cClean, John Robinson. 23 Great George-street, Westminster.
 1859. †Maclear, Sir Thomas, F.R.S., F.R.G.S., F.R.A.S., Astronomer Royal
 at the Cape of Good Hope.
 1862. †Macleod, Henry Dunning. 17 Gloucester-terrace, Camden-hill-road,
 London.
 1855. †M^cLintock, William. Lochinch, Pollokshaws, Glasgow.
 1861. *Maclure, John William. 2 Bond-street, Manchester.
 M^cMaster, Maxwell. 97 Grafton-street, Dublin.
 1852. †M^cMechan, John, M.D. White House, Belfast.
 1862. †Macmillan, Alexander. 1 Trinity-street, Cambridge.
 1855. †M^cNab, John. Edinburgh.
 MacNeill, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S.
 Granton House, Edinburgh.
 MacNeill, Sir John, LL.D., F.R.S., M.R.I.A., Professor of Civil
 Engineering in Trinity College, Dublin. Mount Pleasant,
 Dundalk.
 1854. †M^cNicholl, H., M.D. 42 Oxford-street, Liverpool.
 1850. †Macnight, Alexander. 12 London-street, Edinburgh.
 1859. †Macpherson, Rev. W. Kilmuir Easter, Scotland.
 Macredie, P. B. Mure, F.R.S.E. Irvine, Ayrshire.
 1854. †Macrorie, Dr. 126 Duke-street, Liverpool.
 1852. *Macrory, Adam John. Duncairn, Belfast.

Year of
Election.

- *Macrory, Edmund. 7 Fig-tree-court, Temple, London.
1855. †M'Tyre, William, M.D. Maybole, Ayrshire.
1855. †Macvicar, Rev. John Gibson, D.D. Moffat, near Glasgow.
1857. †Madden, Richard R. Rathmines, Dublin.
- Magor, J. B. Redruth, Cornwall.
1853. †Magrath, Rev. Folliot, A.M. Stradbally, Queen's County, Ireland.
- *Malahide, Talbot de, Lord, F.R.S. Malahide Castle, Malahide, Ireland.
1853. †Malan, John. Holmpton, Holderness.
- *Malcolm, Frederick. 8 Paternoster-row, London.
- Malcolm, Neil. Portalloch, Lochgilphead.
1850. †Malcolm, R. B., M.D., F.R.S.E. 126 George-street, Edinburgh.
- Maley, A. J.
1863. †Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
- *Mallet, Robert, Ph.D., F.R.S., F.G.S., M.R.I.A. 11 Bridge-street, Westminster, London; and The Grove, Clapham-road, Clapham, London.
1857. †Mallet, Dr. John William. University of Alabama, U. S.
1846. †Manby, Charles, F.R.S., F.G.S. 15 Harley-street, London.
- *Manchester, James Prince Lee, Lord Bishop of, F.R.S., F.G.S., F.R.G.S., F.C.P.S. Mauldreth Hall, Manchester.
1863. †Mancini, Count de, Italian Consul.
- Manning, The Right Rev. H.
1864. §Mansel, J. C. Long Thorns, Blandford.
1865. §March, J. F. Fairfield House, Warrington.
1864. §Markham, Clements R., F.R.G.S. 21 Eccleston-square, Pimlico, London.
1852. †Marland, James William. Mountjoy-place, Dublin.
1863. †Marley, John. Mining Office, Darlington.
- *Marling, Samuel S. Stanley Park, Stroud, Gloucestershire.
- Marriott, John. Allerton, Liverpool.
1857. §Marriott, William. Leeds-road, Huddersfield.
1858. †Marriott, William Thomas. Wakefield.
1842. Marsden, Richard. Norfolk-street, Manchester.
- Marsh, Sir Henry, Bart., M.D., M.R.I.A. 9 Merrion-square North, Dublin.
1856. †Marsh, M. H. Wilbury Park, Wilts.
1864. §Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
- Marshall, James. Headingly, near Leeds.
1852. †Marshall, James D. Holywood, Belfast.
- *Marshall, James Garth, M.A., F.G.S. Headingly, near Leeds.
1858. †Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.
1865. §Marten, E. B. 13 High-street, Stourbridge.
- Martin, Rev. Francis, M.A. Trinity College, Cambridge.
- *Martin, Francis P. Brouncker.
1848. †Martin, Henry D. 4 Imperial Circus, Cheltenham.
- Martin, James.
- Martin, Studley. 107 Bedford-street South, Liverpool.
- *Martindale, Nicholas. Peter-lane, Hanover-street, Liverpool.
- *Martineau, Rev. James. 10 Gordon-street, Gordon-square, London.
1865. §Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. §Martineau, Thomas.
1847. †Maskelyne, Nevil Story, M.A., F.G.S. British Museum, London.
1861. *Mason, Hugh. Ashton-under-Lyne.
- *Mason, Thomas. York.
- Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
- *Mather, Daniel. 58 Mount Pleasant, Liverpool.
- *Mather, John. 58 Mount Pleasant, Liverpool.

Year of
Election.

1863. *Mather, Joseph. Beech Grove, Newcastle-on-Tyne.
 1865. *Mathews, G. S. Edgbaston House, Hagley-road, Birmingham.
 1861. *Mathews, William, jun., M.A., F.G.S. 51 Carpenter-road, Birmingham.
 Mathews, William P.
 1859. †Matthew, Alexander C. 3 Canal-terrace, Aberdeen.
 1865. §Matthews, C. E. Waterloo-street, Birmingham.
 1858. †Matthews, F. C. Mandre Works, Driffield, Yorkshire.
 *Matthews, Henry, F.C.S. 60 Gower-street, London, W.C.
 1860. §Matthews, Rev. Richard Brown. The Vicarage, Shalford, near Guildford.
 1863. *Matthiessen, Augustus, Ph.D., F.R.S., Lecturer on Chemistry, St. Mary's Hospital. Paddington, London.
 1857. †Maughan, Rev. J. D.
 1863. †Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
 1855. †Maule, Rev. Thomas, M.A. Partick, near Glasgow.
 1865. *Maw, George, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Salop.
 1863. *Mawson, John. 3 Moseley-street, Newcastle-on-Tyne.
 1864. *Maxwell, Francis. Gribton, near Dumfries.
 *Maxwell, James Clerk, M.A., F.R.S., L. & E., Professor of Natural Philosophy and Astronomy in King's College, London. 8 Palace Garden-terrace, Kensington, London.
 1855. *Maxwell, Sir John, Bart., F.R.S. Pollok House, Renfrewshire.
 1852. †Maxwell, John Waring. Finnebrogue, Downpatrick, Ireland.
 *Maxwell, Robert Percival. Finnebrogue, Downpatrick, Ireland.
 Maynard, Thomas.
 1865. *May, Walter. Berkeley-street, Birmingham.
 *Mayne, Rev. Charles, M.R.I.A. 22 Upper Merrion-street, Dublin.
 Mayne, Edward Ellis.
 1857. †Mayne, William Annesley. Dublin.
 1842. *Meadows, James. York-place, Rusholme, near Manchester.
 1863. §Mease, George D. South Shields.
 1863. §Mease, Solomon. North Shields.
 Meath, Joseph Henderson Singer, D.D., Lord Bishop of.
 1861. §Medcalf, William. 20 Bridgewater-place, Manchester.
 1863. §Meier, R. Newcastle-upon-Tyne.
 Mellor, J.
 1854. †Melly, Charles Pierre. Liverpool.
 1847. †Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
 1863. †Melvin, Alexander. 6 Fingal-place, Edinburgh.
 1862. §Mennell, Henry. 20 Fenchurch-street, London.
 1863. §Messent, P. T. 4 Northumberland-terrace, Tynemouth.
 1847. †Meyer, Charles, D.C.L.
 1847. *Michell, Rev. Richard, B.D. St. Giles's-street, Oxford.
 1865. §Michie, Alexander. 26 Austin Friars, London.
 1865. §Middlemore, William. Edgbaston, Birmingham.
 1855. †Miles, Rev. Charles P., M.D., Principal of the Malta Protestant College, St. Julian's, Malta. Office, 3 St. James's-street, Pall Mall, London.
 1857. †Millar, George M.
 1850. †Millar, James S. 9 Roxburgh-street, Edinburgh.
 1859. †Millar, John. Lisburn, Ireland.
 1863. §Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London.
 Millar, Thomas, M.A. Perth.
 1859. †Miller, James, jun. Greenock.
 1865. §Miller, Rev. J. C., D.D. The Vicarage, Greenwich, London.
 *Miller, Patrick, M.D. Exeter.

Year of
Election.

1861. *Miller, Robert. 30 King-street; and Whalley Range, Manchester.
 1863. †Miller, Thomas. Righill Hall, Durham.
 *Miller, William Allen, M.D., Treas. and V.P.R.S., Pres. Chem. Soc.,
 Professor of Chemistry in King's College, London.
 Miller, William Hallows, M.A., For. Sec. R.S., F.G.S., Professor of
 Mineralogy in the University of Cambridge. 7 Scroope-terrace,
 Cambridge.
 1842. Milligan, Robert. Acacia in Randon, Leeds.
 *Mills, John Robert. Bootham, York.
 1851. †Mills, Rev. Thomas.
 1847. †Milman, The Very Rev. H. H., Dean of St. Paul's, London.
 Milne, Rear-Admiral Sir Alexander, K.C.B., F.R.S.E. Mussel-
 borough, Edinburgh.
 *Milne-Home, David, M.A., F.R.S.E. Wedderburn, Coldstream, N.B.
 1854. *Milner, William. Liverpool.
 1854. *Milner, William Ralph. Wakefield, Yorkshire.
 1864. *Milton, The Rt. Hon. Lord, M.P., F.R.G.S. Wentworth, York-
 shire.
 1865. §Minton, Samuel, F.G.S. Oakham House, near Dudley.
 1855. †Mirrlees, James Buchanan. 128 West-street, Tradeston, Glasgow.
 1859. †Mitchell, Alexander, M.D. Old Rain, Aberdeen.
 1863. †Mitchell, C. Walker, Newcastle-on-Tyne.
 1855. †Mitchell, George. Glasgow.
 1863. *Mitchell, William Stephen, LL.B., F.G.S. Caius College, Cam-
 bridge.
 1855. *Moffat, John, C.E. Ardrossan.
 1854. §Moffat, Thomas, M.D., F.G.S., F.R.A.S., M.B.M.S. Hawarden,
 Chester.
 1864. †Mogg, John Rees. High Littleton House, near Bristol.
 1848. †Moggridge, Matthew. Willows, near Swansea.
 1855. §Moir, James. 174 Gallogate, Glasgow.
 1850. †Moir, John, M.D. Edinburgh.
 1861. †Molesworth, Rev. W. N., M.A. Spotland, Rochdale.
 Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
 1852. †Molony, William, LL.D. Carrickfergus.
 Molyneux, James.
 1865. §Molyneux, William, F.G.S. Branston Cottage, Burton-upon-Trent.
 1853. †Monday, William, Hon. Sec. Hull Lit. and Phil. Soc. 6 Jarratt-
 street, Hull.
 1860. §Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Hyham,
 Ferrers, Northamptonshire.
 1853. †Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
 1850. †Monteith, Alexander E. Inverleith House.
 Montgomery, Matthew. Glasgow.
 1846. †Moody, T. H. C.
 1857. §Moore, Arthur. Cradley House, Clifton, Bristol.
 1859. §Moore, Charles, F.G.S. 6 Cambridge-terrace, Bath.
 1857. †Moore, Rev. Dr. Clontarf, Dublin.
 Moore, John. 2 Mendiam-place, Clifton, Bristol.
 *Moore, John Carrick, M.A., F.R.S., F.G.S. Corswall, Wigtonshire.
 1854. †Moore, Thomas John. Derby Museum, Liverpool.
 Moore, William D. 7 South Anne-street, Dublin.
 1857. *Moore, Rev. William Prior. The College, Cavan, Ireland.
 Morant, Rev. James.
 1861. †Morewood, Edmund. Cheam, Surrey.
 Morgan, Captain Evan, R.A.
 Morgan, James.
 1849. †Morgan, William. 37 Waterloo-street, Birmingham.

Year of
Election.

- Moriarty, Merion, M.D. New South Wales.*
 Morley, George. Park-place, Leeds.
 1863. §Morley, Samuel. Lenton-grove, Nottingham.
 1865. *Morrieson, Captain Robert. Oriental Club, Hanover-square, London.
 1850. †Morrieston, Robert, F.R.S.E. 6 Heriot-row, Edinburgh.
 1861. *Morris, David. 1 Market-place, Manchester.
 1845. †Morris, Edward, M.D. Hereford.
 *Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
 Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
 1861. †Morris, William. The Grange, Salford.
 1863. †Morrow, R. J. Bentick Villas, Newcastle.
 1865. §Mortimer, J. R. Fimber, Malton.
 1854. *Morton, Francis. Hermitage, Oxton, Cheshire; and James-street, Liverpool.
 1857. §Morton, George H., F.G.S. 9 London-road, Liverpool.
 1858. *Morton, Henry Joseph. Garforth House, West Garforth, near Leeds.
 1847. †Moseley, Rev. Henry, M.A., F.R.S. 13 Great George-street, Westminster.
 1857. †Moses, Marcus. 4 Westmoreland-street, Dublin.
 1862. †Mosheimer, Joseph.
 Mosley, Sir Oswald, Bart., D.C.L., F.L.S., F.G.S. Rolleston Hall, Burton-upon-Trent, Staffordshire.
 Moss, John. Otterspool, near Liverpool.
 1853. *Moss, W. H. Kingston-terrace, Hull.
 1864. §Mosse, J. R. General Manager's Office, Mauritius Railway, Port Louis, Mauritius.
 1865. §Mott, Charles Grey. The Park, Birkenhead.
 1862. *Mouat, Frederick John, M.D., Inspector-General of Prisons, Bengal.
 1856. †Mould, Rev. J. G., B.D. 21 Camden-crescent, Bath.
 1863. †Mounsey, Edward. Sunderland.
 Mounsey, John. Sunderland.
 1861. *Mountcastle, William Robert. 22 Dorking-terrace, Cecil-street, Greenheys, Manchester.
 Mowbray, James. Combus, Clackmannan, Scotland.
 1850. †Mowbray, J. T. 27 Dundas-street, Edinburgh.
 Muir, Rev. John. St. Vigean's, by Arbroath.
 1855. §Muir, William. 10 St. John-street, Adelphi, London.
 Muirhead, James. 90 Buchanan-street, Glasgow.
 1852. †Mullan, William. Belfast.
 1857. †Mullins, M. Bernard, M.A., C.E. 1 Fitzwilliam-square South, Dublin.
 Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London.
 1864. *Munro Colonel William. United Service Club, Pall Mall, London.
 1864. §Murch, Jerom. Cranwells, Bath.
 *Murchison, John Henry, F.G.S. Surbiton-hill, Kingston.
 1864. *Murchison, K. R. Manor House, Bathford, Bath.
 *Murchison, Sir Roderick Impey, Bart., K.C.B., M.A., D.C.L. Oxon., LL.D. Camb., F.R.S., F.G.S., F.R.G.S., Hon. Mem. R.S.Ed. & R.I.A., Director-General of the Geological Survey of the United Kingdom. 16 Belgrave-square, London.
 1864. †Murchison, Captain R. M. Caerbaden House, Cleveland-walk, Bath.
 1855. †Murdock, James B. 195 Bath-street, Glasgow.
 1858. †Murgatroyd, William. Bank Field, Bingley.
 Murley, Rev. C. H. South Petherton, Ilminster.
 1856. †Murley, Stephen.
 1852. †Murney, Henry, M.D. 10 Chichester-street, Belfast.

Year of
Election.

1852. †Murphy, Joseph John. Old Forge, Dunmarry, Co. Antrim.
 1850. †Murray, Andrew.
 1857. †Murray, B. A.
 Murray, George.
 Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London; and
 Newsted, Wimbledon, Surrey.
 1859. †Murray, John, M.D. Forres, Scotland.
 *Murray, John, C.E. 11 Great Queen-street, Westminster, London.
 †Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
 1863. †Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
 *Murton, James. Silverdale, near Lancaster.
 Musgrave, The Venerable Charles, D.D., Archdeacon of Craven.
 Halifax.
 1861. †Musgrove, John, jun. Bolton.
 Muspratt, James.
 *Muspratt, James Sheridan, Ph.D., F.C.S. College of Chemistry,
 Liverpool.
 Muston, George.
 1865. §Myers, Rev. E. 17 Summerhill-terrace, Birmingham.
 1845. †Myers, Rev. Thomas. York.
 1859. §Mylne, Robert William, F.R.S., F.G.S., F.S.A. 21 Whitehall-place,
 London.
 1850. †Myrtle, J. Y., M.D. 113 Princes-street, Edinburgh.
 1850. †Nachot, H. W., Ph.D. 113 Princes-street, Edinburgh.
 1842. Nadin, Joseph. Manchester.
 1864. §Napier, Charles Ottley Groom, Southwell Cottage, Kingsdown,
 Bristol.
 1855. †Napier, James R. 22 Blythwood-square, Glasgow.
 1839. *Napier, Right Honourable Joseph. 4 Merrion-square, Dublin.
 *Napier, Captain Johnstone.
 1855. †Napier, Robert. West Chandon, Gareloch, Glasgow.
 Napper, James William L. Loughcrew, Oldcastle., Co. Meath.
 1850. *Nasmyth, James. Penge Hurst, Kent.
 Nasmyth, Robert, F.R.S.E. 5 Charlotte-square, Edinburgh.
 1864. †Natal, Lord Bishop of.
 1860. †Neate, Charles, M.A., M.P. Oriel College, Oxford.
 1850. †Necker, Theodore. Geneva.
 1845. †Neild, Arthur. Ollernshaw, Whaleybridge, by Stockport.
 1853. †Neill, William, Governor of Hull Jail. Hull.
 Neilson, James B. Glasgow.
 Neilson, Robert. Woolton-hill, Liverpool.
 1855. †Neilson, Walter. 172 West George-street.
 1865. §Neilson, W. Montgomerie. Glasgow.
 1846. †Neison, F. G. P.
 1861. *Nelson, William. Scotland Bridge, Manchester.
 1849. †Nesbit, C. J. Lower Kennington-lane, London.
 Ness, John. Helmsley, near York.
 1861. †Nevill, Thomas Henry. 17 George-street, Manchester.
 1857. †Neville, John, C.E., M.R.I.A. Dundalk, Ireland.
 1852. †Neville, Parke, C.E. Town Hall, Dublin.
 1842. New, Herbert. Evesham, Worcestershire.
 Newall, Henry. Hare-hill, Littleborough, Lancashire.
 *Newall, Robert Stirling. Gateshead-upon-Tyne.
 Newberry, Rev. Thomas, M.A. The Rectory, Hinton, Ilminster,
 Somerset.
 Newbigging, P. S. K., M.D. Edinburgh.
 1854. *Newlands, James. 2 Clare-terrace, Liverpool.

Year of
Election.

1854. †*Newman, Charles William.*
 1842. **Newman, Francis William.* 1 Dover-place, Clifton, Bristol.
 **Newman, William.* Darley Hall, near Barnsley, Yorkshire.
 1863. **Newmarch, William, F.R.S.* 17 Palace Gardens-terrace, The Mall,
 Notting-hill, London.
 1853. †*Newmarch, William,* Secretary to Globe Insurance, Cornhill, Lon-
 don.
 1858. †*Newsome, Thomas.* Park-road, Leeds.
 1860. **Newton, Alfred, M.A., F.L.S.* Magdalen College, Cambridge.
 1865. §*Newton, Thomas Henry Goodwin.* Clopton House, near Stratford-
 on-Avon.
 Nicholl, Iltyd, F.L.S. Uske, Monmouthshire.
 1848. †*Nicholl, W. H.* Uske, Monmouthshire.
 **Nicholson, Cornelius, F.G.S.* Welfield, Muswell-hill, London.
 1861. **Nicholson, Edward.* 28 Princess-street, Manchester.
 **Nicholson, John A., A.M., M.B., Lic. Med., M.R.I.A.* Balrath, Kells,
 Co. Meath.
 1858. **Nicholson, William Nicholson.* Roundhay Park, Leeds.
 1850. †*Nicol, J.,* Professor of Natural History in Marischal College, Aberdeen.
 1851. †*Nicolay, Rev. C. G.*
 1856. †*Niven, Rev. James.*
 Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.
 1864. §*Noad, Henry M., Ph.D., F.R.S., F.C.S.* 72 Hereford-road, Bays-
 water, London.
 1863. **Noble, Captain.* Elswick Works, Newcastle-on-Tyne.
 1854. †*Noble, Matthew.* 13 Bruton-street, Bond-street, London.
 1860. **Nolloth, M. S., Captain R.N., F.R.G.S.* St. Mary's Cottage, Peck-
 ham, London; and United Service Club, London.
 1859. †*Norfolk, Richard.* Messrs. W. Rutherford and Co., 14 Canada Dock,
 Liverpool.
 1863. §*Norman, Rev. Alfred Merle, M.A.* Houghton-le-Spring, Co. Durham.
 Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
 Norris, Charles. St. John's House, Halifax.
 1865. §*Norris, Richard.* 2 Birchfield-road, Aston, Birmingham.
 Northampton, Charles Douglas, The Marquis of. 145 Piccadilly,
 London.
 1860. †*Northcote, A. Beauchamp, F.C.S.* Queen's College, Oxford.
 1846. †*Norton, John Howard, M.D.*
 1851. †*Notcutt, S. A.* Westgate-street, Ipswich.
 1861. †*Noton, Thomas.* Priory House, Oldham.
 1851. †*Nourse, William E. C., F.R.C.S.* West Cowes, Isle of Wight.
 Nowell, John. Farnley Hall, Huddersfield.
 1857. †*Nuling, Alfred.*
 1858. †*Nunnerley, Thomas.* Leeds.
 Nurse, William Mountford.
 1859. †*Nuttall, James.* Wellfield House, Todmorden.

 O'Beirne, James, M.D.
 O'Brien, Baron Lucius. Dromoland, Newmarket-on-Fergus, Ireland.
 O'Callaghan, George. Tallas, Co. Clare.
 1858. **O'Callaghan, Patrick, LL.D., D.C.L.* 16 Clarendon-square, Lea-
 mington.
 Odgers, Rev. William James. Sion-hill, Bath.
 1858. **Odling, William, M.B., F.R.S.,* Sec. Chem. Soc., Professor of Che-
 mistry in the Medical School of St. Bartholomew's Hospital.
 Sydenham-road, Croydon, Surrey.
 1857. †*O'Donnavan, William John.* 2 Cloisters, Temple, Dublin.
 1857. †*O'Donnavan, John.* 36 Upper Buckingham-street, Dublin.

Year of
Election.

1859. §Ogilvie, C. W. Norman. Baldovan House, Dundee
*Ogilvie, George, M.D., Lecturer on the Institutes of Medicine in
Marischal College, Aberdeen.
1863. †Ogilvy, G. R. Dundee.
1863. †Ogilvy, Sir John, Bart. Inverquhar, N. B.
1863. †Ogle, Rev. E. C.
*Ogle, William, M.D., M.A. Derby.
O'Grady, Michael M., M.D. Lamancha, Malahide, Dublin.
1859. †Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. †O'Hagan, John. 20 Kildare-street, Dublin.
1862. †O'Kelly, Joseph, M.A. 51 Stephen's Green, Dublin.
1857. †O'Kelly, Matthias J. Dalkey, Ireland.
1853. §Oldham, James, C.E. Austrian Chambers, Hull.
1857. *Oldham, Thomas, M.A., LL.D., F.R.S., F.G.S., M.R.I.A., Director
of the Geological Survey of India. Calcutta.
1860. †O'Leary, Purcell, M.A. Sydney-place, Cork.
1863. †Oliver, D. Richmond, Surrey.
*Ommanney, Erasmus, Rear-Admiral, F.R.A.S., F.R.G.S. 6 Talbot-
square, Hyde-park, London; and United Service Club, Pall
Mall, London.
*O'Reardon, John, M.D.
1847. *Orlebar, A. B., M.A.
1842. Ormerod, George Wareing, M.A., F.G.S. Chagford, Exeter.
1861. †Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Wood-
land-terrace, Cheetham-hill, Manchester.
1858. §Ormerod, T. T. Brighthouse, near Halifax.
Orpen, John H., LL.D., M.R.I.A. (*Local Treasurer*.) 58 Stephen's
Green, Dublin.
1854. †Orr, Sir Andrew. Blythwood-square, Glasgow.
1842. Orrell, Alfred.
1865. §Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
- *Osler, A. Follett, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. Portland-road, Edgbaston, Birmingham.
*Ossalinski, Count.
1854. §Outram, Thomas. Greetland, near Halifax.
Ovenend, Wilson. Sharrow Head, Sheffield.
Overston, Samuel Jones Lloyd, Lord, F.G.S. 22 Norfolk-street,
Park-lane, London; and Wickham Park, Bromley.
1857. †Owen, James H. Park House, Sandymount, Co. Dublin.
Owen, Richard, M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon.
M.R.S.E., Director of the Natural History Department, British
Museum. Sheen Lodge, Mortlake, London.
1863. *Ower, Charles. Dundee.
Oxford, Samuel Wilberforce, D.D., Lord Bishop of, F.R.S., F.S.A.,
F.R.G.S. 26 Pall Mall, London; and Cuddesdon Palace, Wheat-
ley, Oxon.
1855. †Pagan, John M., M.D. West Regent-street, Glasgow.
1850. †Pagan, Samuel Alexander, M.D., F.R.S.E. Edinburgh.
1859. †Page, David, F.R.S.E., F.G.S. 44 Gilmore-place, Edinburgh.
1863. §Paget, Charles. Ruddington Grange, near Nottingham.
1845. †Paget, George E., M.D. Cambridge.
1847. †Pakington, J. S., B.A.
1863. †Palmer, C. M. Whitley Park, near Newcastle-on-Tyne.
*Palmer, Sir William, Bart. Whitechurch-Canonicorum, Dorset.
Palmes, Rev. William Lindsay, M.A. The Vicarage, Hornsea,
Hull.
1854. †Pare, William, F.S.S. Seville Iron Works, Dublin.

Year of
Election.

1857. *Parker, Alexander, M.R.I.A.. William-street, Dublin.
 1863. §Parker, Charles. Dundee.
 *Parker, Charles Stewart. Liverpool.
 1863. †Parker, Henry. Low Elswick, Newcastle-on-Tyne.
 1863. †Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
 Parker, Joseph, F.G.S. Upton Chaney, Bitton, near Bristol.
 1845. †Parker, J. W., jun. Strand, London.
 Parker, Richard. Dunscombe, Cork.
 Parker, Rev. William. Saham, Norfolk.
 1865. *Parker, Walter Mantel. Warren-corner House, near Farnham, Surrey.
 1853. †Parker, William. Thornton-le-Moor, Lincolnshire.
 1861. §Parkes, Alexander. 8 Bath-place, Birmingham.
 1865. *Parkes, Samuel Hickling. 5 St. Mary's-row, Birmingham.
 1864. §Parkes, William. 14 Park-street, Westminster.
 1859. †Parkinson, Robert, Ph.D. Bradford, Yorkshire.
 1863. †Parland, Captain. Stokes Hall, Jesmond, Newcastle-on-Tyne.
 Parnell, E. A.
 1862. §Parnell, John, M.A. Upper Clapton, London.
 Parnell, Richard, M.D., F.R.S.E. 7 James's-place, Leith.
 1854. †Parr, Alfred, M.D. New Brighton, Cheshire.
 Partington, James Edge.
 Partridge, Richard, F.R.S., Professor of Anatomy to the Royal Academy of Arts, and to King's College, London. 17 New-street, Spring-gardens, London.
 1865. *Parsons, Charles Thomas. Ann-street, Birmingham.
 1865. §Pate, Thomas. Ore, Hastings.
 1855. †Paterson, William. 100 Brunswick-street, Glasgow.
 1861. †Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
 1863. †Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
 1863. †Patterson, John. 16 Bloomfield-terrace, Gateshead-on-Tyne.
 *Patterson, Robert, F.R.S. (*Local Treasurer*.) 6 College-square North, Belfast.
 1863. †Pattinson, William. Felling, near Newcastle-on-Tyne.
 1864. §Pattison, Dr. T. H. Edinburgh.
 1863. §Paul, Benjamin H., Ph.D. 8 Gray's Inn-square, London.
 Paul, Henry. *Edinburgh*.
 1863. §Pavy, Frederick William, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-place, London.
 1864. †Payne, Edward Turner. 3 Sydney-place, Bath.
 1851. †Payne, Joseph. Leatherhead, Surrey.
 1847. §Peach, Charles W. 30 Haddington-place, Leith-walk, Edinburgh.
 1863. §Peacock, R. A. Jersey.
 *Pearsall, Thomas John, F.C.S. Mechanics' Institution, Southampton-buildings, Chancery-lane, London.
 1854. †Pearson, J. A. Woolton, Liverpool.
 1853. †Pearson, Robert H. 1 Prospect House, Hull.
 Pearson, Rev. Thomas, M.A.
 1863. §Pease, H. F. Brinkburn, Darlington.
 1852. †Pease, Joseph Robinson, J.P. Hesselwood.
 1863. §Pease, Joseph W. Woodlands, Darlington.
 1863. †Pease, J. W. Newcastle-on-Tyne.
 1858. *Pease, Thomas, F.G.S. Henbury, near Bristol.
 Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
 1855. *Peckover, Alexander, F.R.G.S. Wisbeach, Cambridgeshire.
 *Peckover, Algernon, F.L.S. Wisbeach, Cambridgeshire.

Year of
Election.

- *Peckover, Daniel. Woodhall, Calverley, Leeds.
- *Peckover, William, F.S.A. Wisbeach, Cambridgeshire.
- *Pedler, Lieutenant-Colonel Philip Warren. Mutley House, near Plymouth.
- *Peel, George. Soho Iron Works, Manchester.
- 1861. *Peile, George, jun. Shotley Bridge, near Gateshead-on-Tyne.
- 1861. *Peiser, John. Barnfield House, Oxford-street, Manchester.
- 1865. §Pemberton, Oliver. 18 Temple-row, Birmingham.
- 1861. *Pender, John. Mount-street, Manchester.
- 1856. §Pengelly, William, F.R.S., F.G.S. Lamorna, Torquay.
- 1855. †Penny, Frederick, Professor of Chemistry in the Andersonian University, Glasgow.
- 1849. †Pentland, J. B. 5 Ryder-street, St. James's, London.
- 1845. †Percy, John, M.D., F.R.S., F.G.S., Professor of Metallurgy in the Government School of Mines. Museum of Practical Geology, Jermyn-street, London.
- *Perigal, Frederick. 28 Hereford-square, Brompton, London.
- 1856. †Perkins, A. M.
- 1861. †Perkins, Rev. George. St. James's View, Dickenson-road, Rusholme, near Manchester.
- Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
- 1864. *Perkins, V. R. Wotton-under-Edge.
- 1861. †Perring, John Shae. 104 King-street, Manchester.
- Perry, The Right Rev. Charles, M.A., Bishop of Melbourne, Australia.
- *Perry, Rev. S. G. F., M.A. Tottington Parsonage, near Bury.
- *Peters, Edward. Temple-row, Birmingham.
- 1856. *Petit, Rev. John Louis. 9 New-square, Lincoln's Inn, London.
- 1854. †Petrie, James, M.D. 13 Upper Parliament-street, Liverpool.
- 1861. *Petrie, John. Rochdale.
- 1846. †Petrie, William. Ecclesbourne Cottage, Woolwich.
- Pett, Samuel, F.G.S. 7 Albert-road, Regent's Park, London.
- Peyton, Abel. Birmingham..*
- 1857. †Phayre, George.
- 1845. †Phelps, Rev. Robert, D.D. Cambridge.
- 1863. *Phené, John Samuel, F.R.G.S. 34 Oakley-street, Chelsea, London.
- 1853. *Phillips, Rev. Edward. The Bank, near Chendle, Staffordshire.
- 1853. *Phillips, Herbert. 35 Church-street, Manchester.
- *Phillips, Mark. The Park, near Manchester.
- 1863. §Phillipson, Dr. 59 Blackett-street, Newcastle-on-Tyne.
- 1856. *Phillipps, Sir Thomas, Bart., M.A., F.R.S. Middle-hill, near Broadway, Worcestershire.
- 1859. *Phillips, Major-General Sir Frowell. United Service Club, Pall Mall, London.
- 1850. †Phillips, George. Liverpool.
- 1862. †Phillips, Rev. George, D.D., Queen's College, Cambridge.
- *Phillips, John, M.A., LL.D., D.C.L. (PRESIDENT), F.R.S., F.G.S., Professor of Geology in the University of Oxford. Museum House, Oxford.
- 1859. †Phillips, Major J. Scott.
- Philpott, The Right Rev. Henry, D.D., Lord Bishop of Worcester.
- 1864. §Pickering, William. 3 Bridge-street, Bath.
- 1861. †Pickstone, William. Radcliff Bridge, near Manchester.
- 1856. †Pierson, Charles. 3 Blenheim-parade, Cheltenham.
- Pigott, J. H. Smith. Brockley Hall, Bristol.
- 1865. §Pike, L. Owen. 25 Carlton-villas, Maida Vale, London.
- *Pike, Ebenezer. Besborough, Cork.
- 1864. †Pilditch, Thomas. Portway House, Frome.

Year of
Election.

1857. †Pilkington, Henry M., M.A., Q.C. 35 Gardner's-place, Dublin.
1863. *Pim, Commander Bedford C. T., R.N., F.R.G.S. Junior United Service Club, London.
Pim, George, M.R.I.A. Brennan's Town, Cabinteely, Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
Pim, William H. Monkstown, Dublin.
1861. †Pincoffs, Simon. Crumpsall Lodge, Cheetham-hill, Manchester.
Pinney, Charles. Clifton, Bristol.
1859. †Pirrie, William, M.D. 238 Union-street West, Aberdeen.
1864. †Pitt, R. 5 Widcomb-terrace, Bath.
1865. §Plant, Thomas L. Camp-hill; and 33 Union-street, Birmingham.
1863. *Platt, John. Werneth Park, Oldham, Lancashire.
1842. Playfair, Lyon, C.B., Ph.D., LL.D., F.R.S. L. & E., V.P.C.S., Professor of Chemistry in the University of Edinburgh. 14 Abercromby-place, Edinburgh.
Plumptre, Charles Frederick, D.D., Master of University College, Oxford. University College, Oxford.
Plumtre, R. B., M.A.
1857. †Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *Pochin, Henry Davis, F.C.S. Oakfield House, Salford.
1847. †Pococke, Rev. N., M.A. Queen's College, Oxford.
*Pollexfen, Rev. John Hutton, M.A., Rector of St. Runwald's, Colchester.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A. Polwhele, Truro, Cornwall.
*Pontey, Alexander. Plymouth.
1854. †Poole, *Braithwaite*.
*Poppelwell, Matthew. Rosella-place, Tynemouth.
Porter, Rev. Charles, D.D.
*Porter, Henry John Ker. St. Martin's Abbey, Perth.
1846. †Porter, John.
Porter, Rev. T. H., D.D.
1863. †Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*Potter, Edmund, F.R.S. 10 Charlotte-street, Manchester.
Potter, Henry Glassford, F.L.S., F.G.S. Reform Club, London; and Jesmond High-terrace, Newcastle-on-Tyne.
Potter, Richard, M.A., F.C.P.S. Amphill-square, Hampstead-road, London.
Potter, Samuel T.
1842. Potter, Thomas. George-street, Manchester.
Potter, William. 34 Falkner-street, Liverpool.
1863. †Potts, James. 52½ Quayside, Newcastle-on-Tyne.
1857. *Pounden, Captain Landsdale, F.R.G.S. Junior United Service Club, London; and Brownswood, Co. Wexford.
Powell, Rev. Dr. Madras.
1851. †Power, David.
1857. †Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1859. †Poynter, John. Glasgow.
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1846. †Poyter, Thomas.
1864. §Prangley, Arthur. Ashfield-villas, Cotham, Bristol.
Pratt, Archdeacon, M.A., F.C.P.S. Calcutta.
1864. *Prentice, Manning. Stowmarket, Suffolk.
Prest, Edward, Archdeacon. The College, Durham.
Prest, John. Blossom-street, York.
*Prestwich, Joseph, F.R.S., Treas. G.S. 2 Suffolk-lane, City, London; and 10 Kent-terrace, Regent's Park-road, London.
*Pretious, Thomas. H.M. Dockyard, Devonport.

Year of
Election.

1846. †Priaulx, Nicholas M. 9 Brunswick-place, Southampton.
 1856. *Price, Rev. Bartholomew, M.A., F.R.S., F.R.A.S., Sedleian Professor
 of Natural Philosophy in the University of Oxford. 11 St.
 Giles's-street, Oxford.
 Price, J. T. Neath Abbey, Glamorganshire.
 1865. §Prideaux, J. S. 209 Piccadilly, London.
 1864. *Prior, R. C. A., M.D. Halse House, Taunton.
 1865. *Prichard, Thomas, M.D. Avington Abbey, Northampton.
 1835. *Pritchard, Andrew. 87 St. Paul's-road, Highbury, London.
 1846. *Pritchard, Rev. Charles, M.A., F.R.S., Pres. R.A.S., F.G.S. Hurst-
 hill, Freshwater, Isle of Wight.
 1863. †Procter, R. S. Summerhill-terrace, Newcastle-on-Tyne.
 Proctor, Thomas. Clifton Down, Bristol.
 Proctor, William. Cathay, Bristol.
 1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
 1863. *Prosser, John. 38 Cumberland-road, Newcastle-on-Tyne.
 1841. †Prosser, Richard. King's Norton, near Birmingham.
 Protheroe, Captain W. G. B. Dolewilim, St. Clair's, Carnarvonshire.
 1863. †Proud, Joseph. South Hetton, Newcastle-on-Tyne.
 1849. †Proud, Thomas Aston. Villa-road, Handsworth.
 *Prower, Rev. J. M., M.A. Swindon, Wiltshire.
 1865. §Prowse, Albert P. Plymouth.
 1854. †Puckle, *Hale G.*
 1864. †Pugh, John. Aberdovey, Shrewsbury.
 1859. †Pugh, William. Coalport, Shropshire.
 1854. †Pulsford, *James.*
 1842. *Pumphrey, Charles. 34 Frederick-street, Edgbaston, Birmingham.
 Punnett, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
 1852. †Purdon, Thomas Henry, M.D. Belfast.
 1860. §Purdy, Frederick, F.S.S., Principal of the Statistical Department of
 the Poor Law Board, Whitehall, London. Victoria-road, Ken-
 sington, London.
 1860. *Pusey, S. E. Bouverie. Pusey, Farringdon.
 1861. *Pyne, Joseph John. 63 Piccadilly, Manchester.
 1860. †Radcliffe, Charles Bland, M.D. 4 Henrietta-street, Cavendish-square,
 London.
Radford, J. G.
 *Radford, William, M.D. Sidmount, Sidmouth.
 1861. †Rafferty, Thomas. 13 Monmouth-terrace, Rusholme.
 1854. †Raffles, Thomas Stamford. 21 Canning-street, Liverpool.
 1859. †Raine, George, M.D. 17 Golden-square, Aberdeen.
 1855. †Raine, Harry, M.D. 10 Moore-place, Glasgow.
 1864. †Raine, James T. 8 Widcomb-crescent, Bath.
 Rake, Joseph. Charlotte-street, Bristol.
 1863. §Ramsay, Alexander, jun. 45 Norland-square, Notting Hill, London.
 1845. †Ramsay, Andrew Crombie, F.R.S., F.G.S., Local Director of the
 Geological Survey of Great Britain, and Professor of Geology in
 the Government School of Mines. Museum of Practical Geology,
 Jermyn-street, London.
 1863. †Ramsay, D. R. Wallsend, Newcastle-on-Tyne.
 1861. †Ramsay, John. Kildalton, Argyleshire.
 1845. †Ramsay, *William.* *Glasgow.*
 1858. *Ramsbotham, John Hodgson, M.D. 16 Park-place, Leeds.
 *Rance, Henry. Cambridge.
 Rand, John. Wheatley-hill, Bradford, Yorkshire.
 1865. §Randel, J. 50 Vittoria-street, Birmingham.
 1860. †Randall, Thomas. Grandepoint House, Oxford.

- Year of
Election.
1855. †Randolph, Charles. Pollockshiels, Glasgow.
1847. †Randolph, Captain C. G. Wrotham, Kent.
1860. *Randolph, Rev. Herbert, M.A. Marcham, near Abingdon.
Randolph, Rev. John Honeywood, F.G.S. Sanderstead, Croydon.
Ranelagh, the Right-Hon., Lord. 7 New Burlington-street, Regent-street, London.
1850. §Rankine, William John Macquorn, LL.D., F.R.S. L. & E., Regius Professor of Civil Engineering and Mechanics in the University of Glasgow. 59 St. Vincent-street, Glasgow.
1861. §Ransome, Arthur, M.A. Bowdon, Cheshire.
1851. †Ransome, Frederick. Lower Brook-street, Ipswich.
1851. †Ransome, George.
1849. *Ransome, Robert. Iron Foundry, Ipswich.
Ransome, Thomas. 34 Princess-street, Manchester.
1863. §Ransome, Dr. W. H. Nottingham.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London.
*Ratcliff, Charles, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
1864. §Rate, Rev. John, M.A., Lapley Vicarage, Staffordshire.
Rathbone, Theodore W. Allerton Priory, near Liverpool.
Rathbone, William. Green Bank, Liverpool.
Rathbone, William, jun. 7 Water-street, Liverpool.
1863. †Rattray, W. Aberdeen.
1848. †Ravenshaw, E. C. Athenæum Club, London.
Rawdon, William Frederick, M.D. Bootham, York.
*Rawlins, John. Llewesog Hall, Denbighshire.
1855. *Rawlinson, Major-General Sir Henry C., K.C.B., M.P., LL.D., F.R.S., F.R.G.S. 1 Hill-street, Berkeley-square, London.
Rawson, Rawson William, F.R.G.S.
Rawson, T. S.
*Rawson, Thomas William. Saville Lodge, Halifax.
1865. §Rayner, †Henry. Smethwick, Birmingham.
Read, John.
1845. †Read, Joseph, M.D.
1852. †Read, Thomas, M.D. Donegal-square West, Belfast.
1865. §Read, William. Albion House, Epworth, Bawtry.
1858. †Read, William Henry. Chapel Allerton, near Leeds.
*Read, W. H. Rudstone, M.A., F.L.S. Hayton, near Pocklington, Yorkshire.
*Reade, Rev. Joseph Bancroft, M.A., F.R.S. Bishopbourne Rectory, Canterbury.
1862. *Readwin, Thomas Allison, F.G.S. Stretford, near Manchester.
1864. §Reddie, James, F.R.A.S. Bridge House, Hammersmith, London.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1863. †Redmayne, Giles. 20 New Bond-street, London.
1863. †Redmayne, R. R. 12 Victoria-terrace, Newcastle.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. *Ree, H. P. 27 Faulkner-street, Manchester.
1861. †Reed, Edward J., Chief Constructor of the Navy. Admiralty, Whitehall, London.
1854. †Reid, David Boswell, M.D.
1855. †Reid, James.
1857. †Reid, Robert, M.D., M.R.I.A.
1850. †Reid, William, M.D. Cuivie, Cupar, Fife.
1849. †Reid, Major-General Sir William.
1863. §Renals, E. 'Nottingham Express' Office, Nottingham.
1863. †Rendel, G. Benwell, Newcastle-on-Tyne.

Year of
Election.

- Rennie, Sir John, Knt., F.R.S., F.G.S., F.S.A., F.R.G.S. 32 Charing Cross, London.
1860. †Rennison, Rev. Thomas, M.A. Queen's College, Oxford.
*Renny, Lieutenant H. L., R.E. Montreal.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
1849. †Reynolds, Thomas F., M.D. 14 Lansdowne-terrace, Cheltenham.
Reynolds, William, M.D. Coeddu, near Mold, Flintshire.
1850. †Rhind, William. 121 Princes-street, Edinburgh.
1858. *Rhodes, John. Leeds.
1847. †Ricardo, M. Brighton.
1863. §Richardson, Benjamin W., M.A., M.D. 12 Hinde-street, Manchester-square, London.
1861. §Richardson, Charles. Almondbury, Bristol.
1863. *Richardson, Edward, jun. South Ashfield, Newcastle-on-Tyne.
Richardson, James. Glasgow.
1854. †Richardson, John. Hull.
1863. †Richardson, John W. South Ashfield, Newcastle-on-Tyne.
1859. †Richardson, Sir John S., Bart. Pitfour Castle, Perthshire.
Richardson, Thomas. Glasgow.
Richardson, Thomas. Montpelier-hill, Dublin.
Richardson, William. Micklegate, York.
1861. §Richardson, William. 4 Edward-street, Werneth, Oldham.
Richardson, Rev. William.
1861. †Richson, Rev. Canon, M.A. Shakespeare-street, Ardwick, Manchester.
1863. †Richter, Otto, Ph.D. Bathgate, Linlithgowshire.
*Riddell, Colonel Charles James Buchanan, C.B., F.R.S. Ordnance House, Sheerness.
1861. *Riddell, H. B. The Palace, Maidstone.
1859. †Riddell, Rev. John. Moffat by Beatlock, N. B.
1861. *Rideout, William J. Farnworth, near Manchester.
1862. †Ridgway, Henry Akroyd, B.A. Bank Field, Halifax.
Ridgway, John. Cauldon-place, Potteries, Staffordshire.
1861. §Ridley, John. 19 Belsize-park, Hampstead, London.
1863. †Ridley, Samuel. 7 Regent's-terrace, Newcastle-on-Tyne.
1863. *Rigby, Samuel. Bruch Hall, Warrington.
*Rinder, Miss. Gledhow Grove, Leeds.
1860. §Ritchie, George Robert. 4 Watkin-Terrace, Coldharbour-lane, Camberwell, London.
1855. †Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1853. †Rivay, John V. C. 19 Cowley-street, Westminster, London.
1854. †Robberds, Rev. John, B.A. Liverpool.
1855. †Roberton, James. Gorbals Foundry, Glasgow.
Roberton, John. Oxford-road, Manchester.
1859. †Roberts, George Christopher. Hull.
1859. †Roberts, Henry, F.S.A. Athenæum Club, London.
1854. †Roberts, John.
1853. †Roberts, John Francis. 10 Adam-street, Adelphi, London.
1857. †Roberts, Michael. Trinity College, Dublin.
*Roberts, William P. 50 Ardwick Green, Manchester.
1859. †Robertson, Dr. Andrew. Indego, Aberdeen.
1863. †Robinson, Dr. 26 Welbeck-street, Cavendish-square, London.
1861. §Robinson, Enoch. Dukinfield, Cheshire.
1852. †Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1864. §Robinson, George Augustus. Widcomb-hill, Bath.
1859. †Robinson, Hardy. 156 Union-street, Aberdeen.
1860. †Robinson, Professor H. D.
*Robinson, H. Oliver. 16 Park-street, Westminster, London.

Year of
Election.

- **Robinson, John.*
 1861. †Robinson, John. Atlas Works, Manchester.
 1863. †Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
 1855. †Robinson, M. E. 116 St. Vincent-street, Glasgow.
 1860. †Robinson, Admiral Robert Spencer. 61 Eaton-place, London.
 Robinson, Rev. Thomas Romney, D.D., F.R.S., F.R.A.S., M.R.I.A.,
 Director of the Armagh Observatory. Armagh.
 1863. †Robinson, T. W. U. Houghton-le-Spring, Durham.
 1863. **Robson James. Corlodge Colliery, Bulman's Village, Newcastle-on-Tyne.*
 *Robson, Rev. John, D.D. Glasgow.
 1855. †Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
 1845. †*Rocow, Tattersall Thomas.*
 1851. †Rodwell, William. Woodlands, Holbrook, Ipswich.
 Roe, Henry, M.R.I.A. 2 Fitzwilliam-square East, Dublin.
 1846. †Roe, William Henry. Portland-terrace, Southampton.
 1861. §Rofe, John, F.G.S.
 1860. †Rogers, Professor H. D. Glasgow.
 1860. †Rogers, James E. T., Professor of Political Economy in the University of Oxford. Beaumont-street, Oxford.
 *Roget, Peter Mark, M.D., F.R.S. 18 Upper Bedford-place, Russell-square, London.
 1859. §Rolleston, George, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. 15 New Inn Hall-street, Oxford.
 1863. †Romilly, Edward. 14 Hyde Park-terrace, London.
 1845. †*Romily, Rev. Joseph. Trinity College, Cambridge.*
 1845. †Ronalds, Francis, F.R.S. 9 St. Mary's-villas, Battle, Essex.
 1846. †Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
 1865. §Roper, R. S. Newport, Monmouthshire.
 1861. *Roscoe, Henry Enfield, B.A., Ph.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
 1861. §Rose, C. B., F.G.S. 25 King-street, Great Yarmouth, Norfolk.
 Rosebery, Archibald John, Earl of, K.T., M.A., D.C.L., F.R.S. 139 Piccadilly, London; and Dalmeny Park, Linlithgow.
 1863. †Roseby, John. Haverholme House, Brigg, Lincolnshire.
 1851. †*Rosling, Alfred.*
 1857. †Ross, David, LL.D. Drumbrain Cottage, Newbliss, Ireland.
 1859. *Ross, James Coulman. Trinity College, Cambridge.
 1861. *Ross, Thomas. Featherstone-buildings, High Holborn, London.
 1842. Ross, William. Pendleton, Manchester.
 Rosse, William, Earl of, M.A., K.St.P., LL.D., F.R.S., F.R.A.S., F.G.S., M.R.I.A., F.R.G.S., F.A.S., Chancellor of the University of Dublin. Birr Castle, Parsonstown, King's County, Ireland.
 Rosson, John. Moore Hall, near Ormskirk, Lancashire.
 1855. †Roth, Dr. Matthias. 16A Old Cavendish-street, London.
 1865. *Rothera, George Bell. Nottingham.
 1846. †Roundall, William B. 146 High-street, Southampton.
 *Roundell, Rev. Danson Richardson. Gledstone, Skipton.
 1849. §Rounds, Daniel G. Hange Colliery, near Tipton, Staffordshire.
 1847. †Rouse, William. 16 Canterbury Villas, Maida Vale, London.
 1861. †Routh, Edward J., M.A. St. Peter's College, Cambridge.
 1861. †Rowan, David. St. Vincent Crescent, Glasgow.
 1855. †Rowand, Alexander. Linthouse, near Glasgow.
 1865. §Rowe, Rev. John. Beaufort-villas, Edgbaston, Birmingham.
 1855. *Rowney, Thomas H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
 *Rowntree, Joseph. Leeds.

Year of
Election.

1862. †Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
 1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
 1859. †*Ruland, C. H.*
 1861. *Rumney, Robert, F.C.S. Ardwick, Manchester.
 1856. †Rumsay, Henry Wildbore. Gloucester Lodge, Cheltenham.
 *Rushout, Capt. the Hon. George, F.G.S. 10 Bolton-street, Piccadilly, London.
 1847. †Ruskin, John, M.A., F.G.S. Denmark-hill, Camberwell, London.
 1857. †Russell, Rev. C. W., D.D. Maynooth College.
 1849. †Russell, James, M.D. Temple-row, Birmingham.
 1855. †Russell, James, jun. Falkirk.
 1865. §Russell, James. 91 Newhall-street, Birmingham.
 1859. †Russell, John, Earl, K.G., F.R.S., F.R.G.S. 37 Chesham-place, Belgrave-square, London.
 Russell, John. Piercefield, Chepstow.
 Russell, John. 15 Middle Gardiner's-street, Dublin.
 Russell, John Scott, M.A., F.R.S. L. & E. Sydenham; and 5 Westminster Chambers, Westminster, London.
 1852. *Russell, Norman Scott. 37 Great George-street, Westminster, London.
 1853. †*Russell, Robert.*
 1863. §Russell, Robert. Gosforth Colliery, Newcastle-on-Tyne.
Russell, Rev. T.
 1852. *Russell, William J., Ph.D. 8 Circus-road, St. John's Wood, London.
 1862. §Russell, W. H. L., A.B. Shepperton, Middlesex.
 1865. §Rust, Rev. James, M.A. Manse of Slains, Ellon, N. B.
 Rutson, William. Newby Wiske, Northallerton, Yorkshire.
 1852. †*Ryan, John, M.D.*
 *Ryland, Arthur. Birmingham.
 1865. §Ryland, Thomas. The Redlands, Erdington, Birmingham.
 1853. †Rylands, Joseph. 9 Charlotte-street, Hull.
 1861. *Rylunds, Thomas Glazebrook. Neath House, Warrington.
 *Sabine, Major-General Edward, R.A., LL.D., D.C.L., President of the Royal Society, F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, London.
 1865. §Sabine, Robert. (Care of C. W. Siemens, Esq.), 3 George-street, Westminster.
 Salkeld, Joseph. Penrith, Cumberland.
 1857. †Salmon, Rev. George, D.D., F.R.S., Professor of Mathematics in Trinity College, Dublin.
 1864. †Salmon, Henry C., F.G.S., F.C.S. 36 Cannon-street, London.
 Salmon, William Wroughton. 9 Regent's Park-square, London; and Devizes, Wiltshire.
 1854. *Salt, Charles F. 24 Grove-street, Liverpool.
 1858. *Salt, Titus. Crow Nest, Lightcliffe, Halifax.
 1856. †Salter, John William, F.G.S. Geological Survey of Great Britain, Museum of Practical Geology, Jermyn-street; and 8 Bolton-road, Boundary-road, St. John's Wood, London.
Salisbury, Sir John, Knt.
 1842. Sambrooke, T. G. 32 Eaton-place, London.
 1861. *Samson, Henry. Messrs. Samson and Leppoe, St. Peter's-square, Manchester.
 1854. †Sandbach, Henry R. Hafodunos, Denbighshire.
 1861. *Sandeman, A., M.A. Queen's College, Cambridge.
 1857. †Sanders, Gilbert. 2 Foster-place, Dublin.
 Sanders, John Naish, F.G.S. 12 Vyvyan-terrace, Clifton, Bristol.
 *Sanders, William, F.R.S., F.G.S. (*Local Treasurer.*) 21 Richmond-terrace, Clifton, Bristol.

Year of
Election.

- Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. §Sandford, William. 9 Springfield-place, Bath.
1854. †Sandon, Lord. 39 Gloucester-square, London.
1864. §Sanford, William A. Nynehead Court, Wellington, Somersetshire.
1865. §Sargant, W. L. Edmund-street, Birmingham.
- Satterfield, Joshua. Alderley Edge.
1861. †Saul, Charles J. Smedley-lane, Cheetham-hill, Manchester.
1846. †Saunders, Trelawney William.
1864. †Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. Manor House, Ifley, near Oxford.
1863. †Savory, Valentine. Cleckheaton, near Leeds.
- Saxby, Stephen Martin.
1857. †Scallan, James Joseph. 77 Harcourt-street, Dublin.
1850. †Scarth, Pillans. 28 Barnard-street, Leith.
- *Schemman, J. C. Hamburg.
- *Schlick, Commandeur de. 15 Rue Bellechasse, Faubourg St. Germain, Paris.
1842. Schofield, Benjamin.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1842. Schofield, W. F. Fairlawn, Ripon.
- Scholefield, William. Birmingham.
- *Scholes, T. Seddon. 16 Dale-street, Leamington.
1847. *Scholey, William Stephenson, M.A. Freemantle Lodge, Castle-hill, Reading.
- *Scholfield, Edward, M.D. Doncaster.
1854. †Scholfield, Henry D., M.D.
- Schunck, Edward, F.R.S. Oaklands, Kersall Moor, Manchester.
1861. *Schwabe, Edmund Salis. Rhodes House, near Manchester.
1847. †Sclater, Philip Lutley, M.A., Ph.D., F.R.S., F.L.S., Sec. Zool. Soc. 11 Hanover-square, London.
1849. †Scoffern, John, M.B. Barnard's Inn, London; and Ilford, Essex.
1865. §Scott, Major-General, Royal Bengal Artillery. Treledan Hall, Montgomeryshire.
1859. †Scott, Captain Fitzmaurice. Forfar Artillery.
1855. †Scott, Montague D., B.A. Hove, Sussex.
1857. §Scott, Robert H. 43 Wellington-place, Upper Leeson-street, Dublin.
1861. §Scott, Rev. Robert Selkirk, M.A. 7 Beaufort-terrace, Cecil-street, Manchester.
1864. §Scott, Wentworth Lascelles, F.C.S. Cornwall-villa, 24 Cornwall-road, Westbourne Park, London.
1858. †Scott, William. Holbeck, near Leeds.
1864. §Scott, William Robson, Ph.D. St. Leonards, Exeter.
1856. †Scougall, James.
1854. †Scrivenor, Harry. Ramsay, Isle of Man.
1859. †Seaton, John Love. Hull.
- *Sedgwick, Rev. Adam, M.A., LL.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., F.R.G.S., Woodwardian Professor of Geology in the University of Cambridge, and Canon of Norwich. Trinity College, Cambridge.
1853. †Sedgwick, Rev. James. Scalby Vicarage, Scarborough.
1861. *Seeley, Harry, F.G.S. Woodwardian Museum, Cambridge.
- Selby, Prideaux John, F.L.S., F.G.S. Twizel House, Belford, Northumberland.
1855. †Seligman, H. L. 135 Buchanan-street, Glasgow.
1850. †Seller, William, M.D. 23 Nelson-street, Edinburgh.
- Selwyn, Rev. William, M.A., Prebendary of Ely. Foxton, Royston.
1858. *Senior, George. Barnsley.

Year of
Election.

- Seymour, George Hicks. Stonegate, York.
1861. *Seymour, Henry D., M.P. 39 Upper Grosvenor-street, London.
Seymour, John. 21 Bootham, York.
1853. †Shackles, G. L. 6 Albion-street, Hull.
*Shaen, William. 8 Bedford-row, London.
1846. †Sharp, James. 22 Oxford-street, Southampton.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. §Sharp, Samuel, F.G.S., F.S.A. Dallington Hall, near Northampton.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1854. †Sharpe, Robert, M.D.
Sharpey, William, M.D., LL.D., Sec. R.S., F.R.S.E., Professor of
Anatomy in University College. 33 Woburn-place, London.
1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1858. †Shaw, Edward W. 3 Albion-place, Leeds.
1865. §Shaw, George. Cannon-street, Birmingham.
1845. †Shaw, John, M.D., F.L.S., F.G.S. Boston, Lincolnshire.
1861. *Shaw, John. City-road, Hulme, Manchester.
1858. †Shaw, John Hope. Headingley, Leeds.
1853. †Shaw, Norton, M.D.
Shepard, John. Nelson-square, Bradford, Yorkshire.
1863. †Shepherd, A. B. 7 South-square, Gray's Inn, London.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
- *Sherrard, David Henry. 88 Upper Dorset-street, Dublin.
1851. †Shewell, John T. Rushmere, Ipswich.
Shore, Offley. Sheffield.
1849. †Shorthouse, Joseph. Birmingham.
1846. *Shortrede, Colonel Robert, F.R.A.S. 6 Medina Villas, Brighton.
1864. §Showers, Lieut.-Colonel Charles L. Cox's Hotel, Jermyn-street,
London.
1842. Shuttlesworth, John. Wilton Polygon, Cheetham-hill, Manchester.
1861. *Sidebotham, Joseph. 19 George-street, Manchester.
1861. *Sidebottom, James. Portland-street, Manchester.
1861. *Sidebottom, James, jun. Spring-bank Mills, Stockport.
1857. †Sidney, Frederick John. 19 Herbert-street, Dublin.
Sidney, M. J. F. Cowpen, Newcastle-upon-tyne.
1857. †Siegfried, Rudolph Th.
1856. §Siemens, C. William, F.R.S. 3 Great George-street, Westminster,
London.
Sigmond, George, M.D., F.S.A.
- *Sillar, Zechariah, M.D. Bath House, Laurie Park, Sydenham, near
London.
1859. †Sim, John. Hardgate, Aberdeen.
1855. †Sim, William. Furnace, near Inverary.
1851. †Sim, W. D. Ipswich.
1862. §Simms, James. 138 Fleet-street, London.
1852. †Simms, William. Albion-place, Belfast.
1847. †Simon, John. King's College, London.
1850. †Simpson, Professor James Y.
1859. †Simpson, John. Marykirk, Kincardineshire.
1863. §Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. †Simpson, Max, M.D.
*Simpson, Rev. Samuel. Douglas, Isle of Man.
Simpson, Thomas.
- Simpson, Thomas. Blake-street, York.
- Simpson, William. Bradmore House, Hammersmith, London.
1859. †Sinclair, Alexander. 133 George-street, Edinburgh.

Year of
Election.

1850. †Sinclair, Rev. William. Leeds.
 1864. *Sircar, Baboo Mohendro Lall, M.D. (Care of Edwin Goodive, Esq.,
 Dunagh, Stoke Bishop, Bristol).
 *Sirr, Rev. Joseph D'Arey, D.D., M.R.I.A. Castle-hill, Winchester.
 Sisson, William, F.G.S. Clifton, Bristol.
 1865. §Sissons, W. South Church Side, Hull.
 1850. †Skæe, David, M.D. Royal Asylum, Edinburgh.
 1850. †Skane, William Forbes.
 1859. †Skinner, James. Dromin, Listowel, Ireland.
 1849. †Slaney, R. A. Shropshire.
 1842. *Slater, William. Princess-street, Manchester.
 1853. §Sleddon, Francis. 2 Kingston-terrace, Hull.
 *Sleeman, Philip.
 1849. §Sloper, George Edgar, jun. Devizes.
 1849. †Sloper, Samuel W. Devizes.
 1860. §Sloper, S. Elgar. Winterton, near Southampton.
 1858. †Smeeton, G. H. Commercial-street, Leeds.
 1857. †Smith, Aquila, M.D., M.R.I.A. 121 Lower Bagot-street, Dublin.
 Smith, Archibald, M.A., F.R.S. L. & E. River-bank, Putney; and
 3 Stone-buildings, Lincoln's Inn, London.
 1860. §Smith, Brooke. 65 Hill-street, Birmingham.
 Smith, Rev. B., F.S.A.
 1861. *Smith, Charles Edward, F.R.A.S. Fir Vale, near Sheffield.
 1865. §Smith, David, F.R.A.S. 4 Cherry-street, Birmingham.
 1853. †Smith, Edmund. Ferriby, near Hull.
 1859. §Smith, Edward, M.D., LL.B., F.R.S. 16 Queen Anne-street, London.
 1865. §Smith, Frederick. The Priory, Dudley.
 1855. †Smith, George. Port Dundas, Glasgow.
 1855. †Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.
 *Smith, Rev. George Sidney, D.D., M.R.I.A., Professor of Biblical
 Greek in the University of Dublin. Aughalurcher, Five-mile-
 Town, Co. Tyrone.
 1859. †Smith, G. Campbell. Banff.
 1859. †Smith, Henry A. 5 East Craibstone-street, Aberdeen.
 *Smith, Henry John Stephen, M.A., F.R.S., Savilian Professor of
 Geometry in the University of Oxford. 64 St. Giles's, Oxford.
 1860. *Smith, Heywood., M.A., M.B. 25 Park-street, Grosvenor-square,
 London.
 1845. †Smith, Horatio. Manchester.
 1865. §Smith, Isaac. 26 Lancaster-street, Birmingham.
 1842. *Smith, James. Berkeley House, Seaforth, near Liverpool.
 Smith, James, F.R.S. L. & E., F.G.S., F.R.G.S. Athenæum Club,
 London; and Jordan-hill, Glasgow.
 1859. †Smith, James. Gibraltar.
 1855. †Smith, James. St. Vincent-street, Glasgow.
 *Smith, John. Shelbrook House, Ashby-de-la-Zouch.
 1850. †Smith, John, M.D. Edinburgh.
 1853. †Smith, John. York City and County Bank, Malton, Yorkshire
 1854. †Smith, John. Commerce-court, Liverpool.
 1858. *Smith, John Metcalf. (Local Treasurer.) Bank, Leeds.
 Smith, John Peter George. Liverpool.
 1864. §Smith, John S. Sydney Lodge, Wimbledon, Surrey.
 1852. *Smith, Rev. Joseph Denham. Kingstown, near Dublin.
 1861. †Smith, Professor J., M.D. University of Sydney, Australia.
 1845. †Smith, Rev. J. J. Caius College, Cambridge.
 *Smith, Rev. Philip, B.A. 33 Upper Bedford-place, Russell-square,
 London.

Year of
Election.

1860. *Smith, Protheroe, M.D. 25 Park-street, Grosvenor-square, London.
 1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
 1847. †Smith, Robert Angus, Ph.D., F.R.S., F.C.S. 20 Grosvenor-square, Manchester.
 *Smith, Robert Mackay. Bellevue-crescent, Edinburgh.
 1859. †Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
 1852. †Smith, William. Eglinton Engine Works, Glasgow.
 1857. §Smith, William, C.E., F.G.S. 19 Salisbury-street, Adelphi, London.
 1850. *Smyth, Charles Piazzi, F.R.S. L. & E., F.R.A.S., Astronomer Royal for Scotland, Professor of Practical Astronomy in the University of Edinburgh. 1 Hillside-crescent, Edinburgh.
 1846. †Smyth, Rev. George Watson.
 1857. *Smyth, John, jun., M.A., C.E. Milltown, Banbridge, Ireland.
 1864. §Smyth, Warington W., M.A., F.R.S., Pres. G.S., Lecturer on Mining at the Government School of Mines, and Inspector of the Mineral Property of the Crown. Jermyn-street; and 27 Victoria-street, London.
 1854. †Smythe, Lieut.-Col. W. J., R.A. Woolwich.
 1850. †Smyttan, George, M.D. Edinburgh.
 Soden, John. Athenæum Club, Pall Mall, London.
 1853. †Sollitt, J. D., Head Master of Grammar School, Hull.
 *Solly, Edward, F.R.S., F.S.A. Holme Court, Isleworth, Middlesex.
 *Solly, Samuel Reynolds, M.A., F.R.S. 10 Manchester-square, London.
 *Sopwith, Thomas, M.A., F.R.S., F.G.S., F.R.G.S. 103 Victoria-street, Westminster, London.
 Sorbey, Alfred. South Darley, near Matlock, Derbyshire.
 1859. *Sorby, H. Clifton, F.R.S., F.G.S. Broomfield, Sheffield.
 1861. †Sorensen, Le Chevalier B. Norway.
 1865. *Southall, John Tertius. Leominster.
 1859. †Southall, Norman. 44 Cannon-street West, London.
 1849. †Southall, Thomas. Willington-road, Birmingham.
 1856. †Southwood, Rev. T. A. Cheltenham College.
 1863. †Sowerby, John. Shipcote House, Gateshead, Durham.
 1863. *Spark, H. K. Greenbank, Darlington.
 Speir, Thomas.
 1859. †Spence, Rev. James, D.D. 6 Clapton-square, London.
 *Spence, Joseph. Pavement, York.
 1854. §Spence, Peter. Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester.
 1845. †Spence, W. B.
 1861. §Spencer, John Frederick. St. Nicholas-buildings, Newcastle-on-Tyne.
 1861. *Spencer, Joseph. 27 Brown-street, Manchester.
 1863. *Spencer, Thomas.
 1855. †Spens, William. 78 St. Vincent-street, Glasgow.
 1864. *Spicer, Henry, jun. 19 New Bridge-street, Blackfriars, London.
 Spicer, Thomas Trevetham, M.A., LL.D.
 1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London.
 1847. *Spiers, Richard James, F.S.A. 14 St. Giles's-street, Oxford.
 1864. *Spiller, Captain John, F.C.S. Chemical Department, Royal Arsenal, Woolwich.
 1846. *Spottiswoode, William, M.A., F.R.S., F.R.A.S., F.R.G.S. (*General Treasurer*.) 50 Grosvenor-place, London.
 1864. *Spottiswoode, W. Hugh. 50 Grosvenor-place, London.
 1854. *Sprague, Thomas Bond. 18 Lincoln's Inn Fields, London.
 1853. †Spratt, Joseph James. West Parade, Hull.
 Square, Joseph Elliot. Plymouth.
 *Squire, Lovell. Falmouth.
 1859. †Stables, William Alexander. Cawdor Castle.

Year of
Election.

1857. †*Stack, Thomas. Dublin.*
 1858. **Stainton, Henry T., F.L.S., F.G.S. Mountsfield, Lewisham, Kent.*
 1851. **Stainton, James Joseph, F.L.S., F.C.S. Horsell, near Ripley, Surrey.*
 Stamforth, Rev. Thomas.
 Stanfeld, Hamer. Burley, near Otley.
 1858. †*Stanfield, Alfred W. Wakefield.*
 1865. §*Stanford, E. C. C. 1 Holyrood-crescent, Glasgow.*
 1856. **Stanley, The Right Hon. Lord, M.P., LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London; and Knowsley, Liverpool.*
 Stanley, The Very Rev. Arthur Penrhyn, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London.
 Stanway, J. Holt.
 Stapleton, H. M. 1 Mountjoy-place, Dublin.
 1850. †*Stark, James, M.D., F.R.S.E. 21 Rutland-street, Edinburgh.*
 1863. †*Stark, Richard M. Hull.*
 1848. †*Statham, Henry Joseph. 27 Mortimer-street, Cavendish-sq., London.*
 Staveley, T. K. Ripon, Yorkshire.
 1857. †*Steel, William Edward, M.D. 15 Hatch-street, Dublin.*
 1863. §*Steele, Rev. Dr. 2 Bathwick-terrace, Bath.*
 1861. †*Steinthal, H. M. Hollywood, Fallowfield, near Manchester.*
 Stenhouse, John, Ph.D. 17 Rodney-street, Pentonville, London.
 1863. §*Sterriker, John. Driffild.*
 1861. **Stern, S. J. 33 George-street, Manchester.*
 §*Stevelly, John, LL.D., Professor of Natural Philosophy in Queen's College, Belfast.*
 1861. **Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London.*
 1863. §*Stevenson, Archibald. South Shields.*
 1850. †*Stevenson, David. 8 Forth-street, Edinburgh.*
 Stevenson, Rev. Edward, M.A.
 1863. **Stevenson, James C. South Shields.*
 1855. *Stewart, Balfour, M.A., LL.D., F.R.S., Superintendent of the Kew Observatory of the British Association. Richmond, Surrey.*
 1864. §*Stewart, Charles. Plymouth.*
 1856. **Stewart, Henry Hutchinson, M.D., M.R.I.A. 71 Eccles-street, Dublin.*
 1859. †*Stewart, John. Glasgow.*
 Stewart, Robert. Glasgow.
 1847. †*Stewart, Robert, M.D. The Asylum, Belfast.*
 **Stirling, Andrew. Lower Mosley-street, Manchester.*
 1865. **Stock, Joseph S. Cannon-street, Birmingham.*
 1849. †*Stock, T. S. Bourn Brook Hall.*
 1862. †*Stockil, William. 5 Church Meadows, Sydenham.*
 Stoddart, George. 11 Russell-square, London.
 1864. §*Stoddart, Walter William, F.G.S. 9 North-street, Bristol.*
 1854. †*Stoep, Charles (Consul). 6 Cook-street, Liverpool.*
 **Stokes, George Gabriel, M.A., D.C.L., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Pembroke College, Cambridge.*
 1845. †*Stokes, Rev. William H., M.A., F.G.S. Cambridge.*
 1862. †*Stone, E. J., M.A. Royal Observatory, Greenwich.*
 1859. †*Stone, Dr. William H. 13 Vigo-street, London.*
 1857. †*Stoney, Bindon B., M.R.I.A. 89 Waterloo-road, Dublin.*
 1861. **Stoney, George Johnstone, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. Dublin Castle, Dublin.*
 1854. †*Store, George. Prospect House, Fairfield, Liverpool.*
 1859. §*Story, James. 17 Bryanston-square, London.*
 Stowe, William. Buckingham.

Year of
Election.

- Stowell, Rev. H. Acton-square, Salford, Manchester.
 Strachan, James M. The Grove, Teddington, Middlesex.
 1859. †*Strachan, Patrick.*
 1863. †Strachan, T. Y. Lovaine-crescent, Newcastle-on-Tyne.
 1863. †Straker, John. Wellington House, Durham.
 1850. †*Strange, John, LL.D. Edinburgh.*
 *Strickland, Arthur. Bridlington Quay, Yorkshire.
 *Strickland, Charles. Loughglyn, Ballaghaderreen, Ireland.
 1845. †*Strickland, Henry Eustatius.*
 Strickland, J. E. French-park, Roscommon, Ireland.
 Strickland, William. French-park, Roscommon, Ireland.
 1859. †Stronach, William, R.E. Ardmellie, Banff.
 Strong, Rev. William. Stanground, near Peterborough.
 1848. †Struvé, William Price. Picton-place, Swansea.
Stroud, Rev. Joseph, M.A.
Stuart, Robert. Manchester.
 1854. †Stuart, William. 1 Rumford-place, Liverpool.
 1861. †*Stuart, W. D. Philadelphia.*
 1859. †*Stuart, William Henry.*
 1864. †Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
 1857. †Sullivan, William K., Ph.D., M.R.I.A. Museum of Irish Industry
 and 53 Upper Leeson-road, Dublin.
 Sutherland, Alexander John, M.D., F.R.S., F.G.S. 6 Richmond-
 terrace, Westminster, London.
 1863. †Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
 1862. *Sutherland, George Granville William, Duke of, F.R.G.S. Stafford
 House, London.
 1855. †Sutton, Edwin. 44 Winchester-street, Pimlico, London.
 1863. §Sutton, F. Bank Plain, Norwich.
 1861. *Swan, Patrick Don S. Kirkaldy, N.B.
 1862. *Swan, William, Professor of Natural Philosophy in the University of
 St. Andrews, N. B.
 1863. †Swan, William. Walker, Durham.
 1853. †*Svan, William Thomas.*
 1862. *Swann, Rev. S. K. Gedling, near Nottingham.
Swanwick, J. W.
 Sweetman, Walter, M.A., M.R.I.A. 4Mountjoy-square North, Dublin.
 1863. §Swindell, J. S. E. Stourbridge.
 1863. †Swinhoe, Robert, F.R.G.S. Oriental Club, London.
 1859. †Sykes, Alfred. Leeds.
 1847. †Sykes, H. P. 47 Albion-street, Hyde Park, London.
 1862. §Sykes, Thomas. Cleckheaton, near Leeds.
 *Sykes, Colonel William Henry, M.P., F.R.S., Hon. M.R.I.A., F.G.S.,
 F.R.G.S. 47 Albion-street, Hyde Park, London.
 1847. †Sykes, W. H. F. 47 Albion-street, Hyde Park, London.
 Sylvester, James Joseph, M.A., LL.D., F.R.S., Professor of Mathe-
 matics in the Royal Military Academy, Woolwich. Woolwich;
 and Athenæum Club, London.
 1850. †Syme, James, Professor of Clinical Surgery in the University of Edin-
 burgh. The College, Edinburgh.
 1856. *Symonds, Frederick, F.R.C.S. Beaumont-street, Oxford.
 1859. §Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi,
 London.
 1860. †Symonds, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
 1859. §Symons, G. J. 136 Camden-road, London.
 1855. *Symons, William, F.C.S. 17 St. Mark's-crescent, Regent's Park,
 London.
 Synge, Rev. Alexander. St. Peter's, Ipswich.

Year of
Election.

- Synge, Francis. Glanmore, Ashford, Co. Wicklow.
Synge, John Hatch. Glanmore, Ashford, Co. Wicklow.
1865. §Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N. B.
§Talbot, William Hawkshead. Southport, Lancashire.
Talbot, William Henry Fox, M.A., LL.D., F.R.S., F.L.S. Lacock Abbey, near Chippenham.
Taprell, William. 7 Westbourne-crescent, Hyde Park, London.
1861. *Tarratt, Henry W. Bushbury Lodge, Leamington.
1856. †Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1864. †Tasker, Rev. J. C. W. 1 Upper Lansdown-villas, Bath.
1857. *Tate, Alexander. 41 Upper Sackville-street, Dublin.
1863. §Tate, John. Alnmouth, near Alnwick, Northumberland.
1854. †Tate, *Lieut.-Colonel*.
1858. *Tatham, George. Leeds.
1864. *Tawney, Edward. 5 Victoria-square, Clifton, Bristol.
*Taylor, Rev. John James, B.A., Principal and Professor of Ecclesiastical History in Manchester New College, London. 22 Woburn-square, London.
Taylor, Captain Edward.
Taylor, Frederick. Messrs. Taylor, Potter & Co., Liverpool.
1854. †Taylor, Dr. H. R. 1 Percy-street, Liverpool.
*Taylor, James. Culverlands, near Reading.
*Taylor, John, F.G.S. 6 Queen-street-place, Upper Thames-street, London.
1861. *Taylor, John, jun. 6 Queen-street-place, Upper Thames-st., London.
1856. †Taylor, John. Oriental Association, Walbrook, London.
1863. §Taylor, John. Earsdon, Newcastle-on-Tyne.
1863. †Taylor, John. Lovaine-place, Newcastle-on-Tyne.
1865. §Taylor, Joseph. 99 Constitution-hill, Birmingham.
*Taylor, *Vice-Admiral J. N., C.B.*
Taylor, Captain P. Meadows, in the Service of His Highness the Nizam. Hyderabad, India.
*Taylor, Richard, F.G.S. 6 Queen-street-place, Upper Thames-street, London.
Taylor, Rev. William, F.R.S., F.R.A.S. Thornloe, Worcester.
*Taylor, William Edward. Millfield House, Enfield, near Accrington.
1858. †Teale, Joseph. Leeds.
Teale, Thomas Pridgin, F.R.S., F.L.S. 28 Albion-street, Leeds.
1858. †Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
Teather, John. Alstonley, Cumberland.
1865. *Templeton, James. Mansion-house School, St. David's, Exeter.
Tennant, Charles. Glasgow.
1863. †Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*Tennant, James, F.G.S., F.R.G.S., Professor of Mineralogy and Geology in King's College, London. 149 Strand, London.
Tennent, R. J. Belfast.
1857. †Tennison, Edward King. Kildare-street Club House, Dublin.
1849. †Teschemacher, E. F. Highbury-park North, London.
1859. †Thain, Rev. Alexander. New Machar.
1848. †Thirlwall, The Right Rev. Connop, D.D. Abergwili, Carmarthen.
1856. †Thodey, Rev. S. Rodborough, Gloucestershire.
Thom, Rev. David, D.D., Ph.D.
Thom, John. Messrs. M^cNaughton & Co., Moseley-street, Manchester.
Thomas, George. Brislington, Bristol.
1848. *Thomas, *George John, M.A.*
1854. †Thompson, Benjamin James. 13 High-street, Liverpool.

- Year of
Election.
1854. † *Thompson, D. P., M.D.* 4 *Salisbury-street, Liverpool.*
 1854. † *Thompson, Edmund.* Cloughton Park, Birkenhead.
 1863. † *Thompson, Rev. Francis.* St. Giles's, Durham.
 1858. * *Thompson, Frederick.* South Parade, Wakefield.
 1859. § *Thompson, George, jun.* Pidsmedden, Aberdeen.
 Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
 Thompson, Henry Stafford. Fairfield, near York.
 1845. † *Thompson, James.* Kirk Houses, Brampton, Cumberland.
 * *Thompson, John.*
 1861. * *Thompson, Joseph.* Woodlands, Wilmslow, near Manchester.
 1864. § *Thompson, Rev. Joseph Hasselgrave, B.A.* Cradley, near Brierley-hill.
 Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
 1853. † *Thompson, Thomas (Austrian Consul).* Hull.
 Thompson, Thomas (Town Clerk). Hull.
 1863. † *Thompson, William.* 11 North-terrace, Newcastle-on-Tyne.
 1850. † *Thomson, Alexander.* Banchory House, by Aberdeen.
 1855. † *Thomson, Allen, M.D.,* Professor of Anatomy. The University,
 Glasgow.
 * *Thomson, Corden, M.D.* Sheffield.
 1852. † *Thomson, Gordon A.* Bedeque House, Belfast.
 Thomson, Guy. Oxford.
 1850. † *Thomson, James.* Kendal.
 1845. † *Thomson, Prof. James, LL.D.*
 1855. † *Thomson, James.* 82 West Nile-street, Glasgow.
 1850. * *Thomson, Professor James, M.A., C.E.* 2 Donegal-square West
 Belfast.
 * *Thomson, James Gibson.* Edinburgh.
 1863. † *Thomson, M.* 8 Meadow-place, Edinburgh.
 1865. § *Thomson, R.W., C.E., F.R.S.E.* Edinburgh.
 Thomson, Thomas. Clitheroe, Lancashire.
 1850. † *Thomson, Thomas, M.D., F.R.S.,* Superintendent of the Botanic
 Garden, Calcutta. Hope House, Kew, London.
 1847. * *Thomson, William, M.A., LL.D., D.C.L., F.R.S. L. & E.,* Professor of
 Natural Philosophy in the University of Glasgow. (*Local*
 Treasurer.) The College, Glasgow.
 1850. † *Thomson, William Hamilton.*
 1850. † *Thomson, Wyville T. C., LL.D., F.G.S.,* Professor of Geology in
 Queen's College, Belfast.
 1854. † *Thorburn, William, M.D.*
 1852. † *Thorburn, Rev. William Reid, M.A.* Starkies, Bury, Lancashire.
 * *Thornton, Samuel.* The Elms, Camp-hill, Birmingham.
 1865. * *Thornley, S.* Sparkbrook, Birmingham.
 1845. † *Thorp, Dr. Disney.* Suffolk Laun, Cheltenham.
 * *Thorp, The Venerable Thomas, B.D., F.G.S.,* Archdeacon of Bristol.
 Kemerton, near Tewkesbury.
 1864. § *Thorp, William, jun.* 13 York-terrace, Kingsland-road, London.
 Thurnam, John, M.D. Devizes.
 1856. † *Tibbs, Somerset.* 58 Regent-street, Cheltenham.
 1865. § *Timmins, Samuel.* Elvetham-road, Edgbaston, Birmingham.
 Tinker, Ebenezer. Mealhill, near Huddersfield.
 * *Tinné, John A., F.R.G.S.* Briarly Aigburth, Liverpool.
 1846. † *Tipper, S. Shirley, near Southampton.*
 Tite, William, M.P., F.R.S., F.G.S., F.S.A. 42 Lowndes-square,
 London.
 Tobin, Rev. John. Liscard, Cheshire.
 1850. † *Tod, James, Sec. Soc. of Arts.* Edinburgh.
 Todd, Rev. James Henthawn, D.D., M.R.I.A. Trinity College,
 Dublin.

Year of
Election.

1859. †Todd, Thomas. Mary Culter House, Aberdeen.
 1861. *Todhunter, Isaac, M.A., F.R.S. St. John's College, Cambridge.
 Todhunter, J. 3 College Green, Dublin.
 1857. †Tombe, Rev. H. J. Ballyfree, Ashford, Co. Wicklow.
 1856. †Tomes, Robert Fisher. Welford, Stratford-on-Avon.
 1864. *Tomlinson, Charles. King's College; and 178 Hampstead-road
 London.
 1863. †Tone, John F. Jesmond Villas, Newcastle-on-Tyne.
 1865. §Tonks, Edmund. Packwood Grange, Knowle, Warwickshire.
 1865. §Tonks, William. 4 Carpenter-road, Edgbaston, Birmingham.
 1865. §Tonks, William Henry. 4 Carpenter-road, Edgbaston, Birmingham.
 1861. *Topham, John, A.I.C.E. 49 Shrubland Grove East, Dalston, Lon-
 don.
 1863. †Torr, F. S. 38 Bedford-row, London.
 1863. †Torrens, R. R. *South Australia*.
 Torrie, Thomas Jameson. Edinburgh.
 1859. †Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus.
 Towgood, Edward. St. Neots, Huntingdonshire.
 1845. †Towler, George V.
 Townend, John.
 Townend, Thomas.
 Townend, T. S.
 1860. †Townsend, John. 11 Burlington-street, Bath.
 1857. †Townsend, Rev. Richard. 33 College, Dublin.
 1861. §Townsend, William. Attleborough Hall, near Nuneaton.
 1854. †Towson, John Thomas. 47 Upper Parliament-street, Liverpool; and
 Local Marine Board, Liverpool.
 1859. †Trail, Rev. Robert, M.A. Boyndie, Banff.
 1859. †Trail, Samuel, LL.D., D.D. The Manse, Hanay, Orkney.
 1850. †Traill, Professor, M.D. Edinburgh.
 Travers, Robert, M.B.
 1865. §Travers, William, F.R.C.S. Charing-cross Hospital, London.
 1851. †Travis, W. H. Whitton, near Ipswich.
 1859. †Trefusis, The Hon. C., M.P. Heaton, Devonshire.
 Tregelles, Nathaniel. Neath Abbey, Glamorganshire.
 Trench, F. A. Newlands House, Clondalkin, Ireland.
 *Trevelyan, Arthur. Wallington, Newcastle-on-Tyne.
 Trevelyan, Sir Walter Calverley, Bart., M.A., F.R.S.E., F.G.S., F.S.A.,
 F.R.G.S. Wallington, Northumberland; and Nettlecombe,
 Somerset.
 1860. §Tristram, Rev. H. B., M.A., F.L.S. Greatham Hospital, near Stockton-
 on-Tees.
 1864. †Truell, Robert. Ballyhenry, Ashford, Co. Wicklow.
 Tuckett, Francis. Frenchay, near Bristol.
 1847. *Tuckett, Francis Fox. Frenchay, near Bristol.
 Tuckett, Frederick. 4 Mortimer-street, Cavendish-square, London.
 Tuckett, Henry. Frenchay, near Bristol.
 1848. †Tudor, Edward Scripp. Bromley, Middlesex.
 Tudor, William.
 Tuke, J. H. Bank, Hitchen.
 Tuke, Samuel. Lawrence-street, York.
 1865. §Turberville, H. Pilton, Barnstaple.
 1854. †Turnbull, James, M.D. 86 Rodney-street, Liverpool.
 1855. §Turnbull, John. 276 George-street, Glasgow.
 1856. †Turnbull, Rev. J. C. 8 Bays-hill Villas, Cheltenham.
 *Turnbull, Rev. Thomas Smith, M.A., F.R.S., F.R.G.S. Blofield,
 Norfolk.
 Turner, Charles.

Year of
Election.

1861. *Turner, James Aspinal. Pendlebury, near Manchester.
Turner, Thomas, M.D. 31 Curzon-street, May Fair, London.
1863. §Turner, William, M.B., F.R.S.E. The University, Edinburgh.
1854. §Tuton, Edward S. Holy Bank, Laurel-road, Fairfield, Liverpool.
1842. Twamley, Charles, F.G.S. 6 Queen's-road, Gloucester Gate, Regent's Park, London.
1859. †Twining, H. R. Grove Lodge, Clapham, London.
1847. †Twining, Richard. 13 Bedford-place, Russell-square.
1847. †Twiss, Travers, D.C.L., F.R.S., F.R.G.S., Regius Professor of Civil Law in the University of Oxford, and Chancellor of the Diocese of London. 19 Park-lane, London.
1846. †Tylor, Alfred, F.G.S., F.L.S. Warwick-lane, London.
1865. §Tylor, E. Burnett. Lindon, Wellington, Somerset.
1858. *Tyndall, John, LL.D., Ph.D., F.R.S., F.C.P.S., Professor of Natural Philosophy in the Royal Institution and Royal School of Mines. Royal Institution, Albemarle-street, London.
- Tyrrell, John. Exeter.
1861. *Tysoe, John. Sedgley-road, Pendleton, near Manchester.
- Upton, Rev. James Samuel, M.A., F.G.S.*
1855. †Ure, John. 114 Montrose-street, Glasgow.
1859. †Urquhart, Rev. Alexander. Tarbat, Ross-shire.
1859. †Urquhart, W. Pollard. Craigston Castle, N. B.; and Castlepollard, Ireland.
- *Vallack, Rev. Benj. W. S. St. Budeaux, near Plymouth.
1854. †Vale, James Theodorick. Hamilton-square, Birkenhead.
- *Vance, Rev. Robert. 16 Montpelier-hill, Dublin.
1863. †Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1853. §Varley, Cornelius. 337 Kentish Town-road, London.
1854. †Varley, Cromwell F.
1865. *Varley, S. Alfred. 66 Roman-road, Holloway, London.
1863. †Vauvert, de Mean A., Vice-Consul for France. Tynemouth.
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.
- Vavasour, Sir Henry Mervyn, Bart.
- Veitch, A. J., M.D.*
- Verney, Sir Harry, Bart. Lower Claydon, Bucks.
- Vernon, George John, Lord. 32 Curzon-street, London; and Sudbury Hall, Derbyshire.
1854. *Vernon, George V., F.R.A.S. Piccadilly Mills; and Old Trafford, Manchester.
1854. *Vernon, John. High Lee, Woolton, Liverpool.
- Veysie, Rev. Daniel, B.D. Daventry.
1864. *Vicary, William, F.G.S. The Priory, Colleston, Exeter.
1859. †Vickers, Thomas.
1854. *Vignoles, Charles, C.E., F.R.S., M.R.I.A., F.R.A.S. 21 Duke-street, Wsetminster, London.
- Visger, Herman. Frenchay, Bristol.
1856. †Vivian, Rev. Edward, B.A. Woodfield, Torquay.
- *Vivian, H. Hussey, M.P., F.G.S. 5 Upper Belgrave-street, London; and Singleton House, Swansea.
1856. §Voelcker, J. Ch. Augustus, Ph.D., F.C.S. 39 Argyll-road, Kensington, London.
- Voelker, Professor Charles. Switzerland.*
- Vye, Nathaniel. Ilfracombe, Devon.

Year of
Election.

1860. § Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
 1859. † Waddington, John. New Dock Works, Leeds.
 1855. * Waldegrave, The Hon. Granville. 26 Portland-place, London.
 1863. † Walker, Alfred O. City of Chester.
 1849. § Walker, Charles V., F.R.S., F.R.A.S. Fernside Villa, Redhill, near Reigate.
 Walker, Sir Edward S. Chester.
 Walker, Francis, F.L.S., F.G.S. Rectory House, The Grove, Highgate.
 Walker, Frederick John. Little Matford, St. Leonard's, near Exeter.
 1859. † Walker, James. 16 Norfolk-crescent, London.
 1855. † Walker, John. 1 Exchange-court, Glasgow.
 1842. * Walker, John. Thorncliffe, Leamington.
 1855. † Walker, John James, M.A. 2 Trinity College, Dublin.
 * Walker, Joseph N., F.L.S. Caldeston, near Liverpool.
 * Walker, Thomas. 10 York-street, Manchester.
 Walker, William. 47 Northumberland-street, Edinburgh.
 Wall, Rev. R. H., M.A. 6 Hume-street, Dublin.
 1863. § Wallace, Alfred R., F.R.G.S. 9 Mark's-crescent, Regent's-park, London.
 1859. † Wallace, William, Ph.D., F.C.S. Chemical Laboratory, 3 Bath-street, Glasgow.
 1856. † Waller, Augustus V., M.D., F.R.S. Bruges.
 1857. † Waller, Edward. Lisenderry, Aughnacloy, Ireland.
 1862. † Wallich, George Charles, M.D., F.L.S. 11 Earls-terrace, Kensington, London.
 Wallinger, Rev. William. Hastings.
 Walmesley, Sir Joshua, Knt. Liverpool.
 Walmesley, Joshua. Lord-street, Liverpool.
 1862. § Walpole, The Right Hon. Spencer Horatio, M.A., D.C.L., M.P., F.R.S. Ealing, near London.
 1857. † Walsh, Albert Jasper. 89 Harcourt-street, Dublin.
 Walsh, John (Prussian Consul). 1 Sir John's Quay, Dublin.
 1855. † Walsh, Richard Hussey, Professor of Political Economy, Dublin.
 1863. † Walters, Robert. Eldon-square, Newcastle-on-Tyne.
 Walton, Thomas Todd. Clifton, Bristol.
 1863. § Wanklyn, James Alfred, F.R.S.E., F.C.S. London Institution, Finsbury-circus, London.
 Wansey, William, F.S.A. Reform Club, Pall Mall.
 1857. † Ward, John S. Prospect-hill, Lisburn, Ireland.
 1847. † Ward, Nathaniel Bagshaw, F.R.S., F.L.S. 14 Clapham Rise, London.
 Ward, Rev. Richard, M.A. 12 Eaton-place, London.
 1863. † Ward, Robert. Dean-street, Newcastle-on-Tyne.
 * Ward, William Sykes, F.C.S. Denison Hall, Leeds.
 Wardell, William. Chester.
 1858. † Wardle, Thomas. Leek Brook, Leek, Staffordshire.
 † Warrington, Robert, F.R.S., F.C.S., Chemical Operator to the Society of Apothecaries. Apothecaries' Hall, London.
 1865. § Waring, Dr. E. J. 3A Talbot-road, Bayswater, London.
 1864. * Warner, Edwin. Higham Hall, Woodford, Essex.
 1856. † Warner, Thomas H. Lee. Tiberton Court, Hereford.
 1865. * Warren, Edward Pritchard. 13 Old-square, Birmingham.
 Warwick, William Atkinson. Wyddrington House, Cheltenham.
 1856. † Washbourne, Buchanan, M.D. Gloucester.
 1847. † Waterhouse, G. R. British Museum, London.
 * Waterhouse, John, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.

Year of
Election.

1854. † Waterhouse Nicholas. 5 Rake-lane, Liverpool.
 1854. † Watkins, James. Bolton.
 1855. † Watson, Ebenezer. 16 Abercromby-place, Glasgow.
 * Watson, Henry Hough, F.C.S. The Folds, Bolton-le-Moors.
 Watson, Hewett Cottrell, F.L.S. Thames Ditton, Surrey.
 Watson, James. Glasgow.
 1855. † Watson, James, M.D. 152 St. Vincent-street, Glasgow.
 1863. † Watson, Joseph. Bensham Grove, near Gateshead-on-Tyne.
 1859. † Watson, J. Forbes. India Office, London.
 1863. § Watson, R. S. Moscroft, Gateshead-on-Tyne.
 1858. † Watson, William. Bilton House, Harrogate.
 Watson, William H.
 1855. † Watt, George. West Regent-street, Glasgow.
 1861. † Watts, Sir James. Abney Hall, Cheadle, near Manchester.
 1846. § Watts, John King, F.R.G.S. St. Ives, Huntingdonshire.
 1858. † Waud, Major E. Manston Hall, near Leeds.
 Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near
 Wickford, Essex.
 1862. § Waugh, Major-General Sir Andrew Scott, R.E., F.R.S., F.R.G.S.,
 late Surveyor-General of India, and Superintendent of the Great
 Trigonometrical Survey. 7 Petersham-terrace, Queen's Gate,
 London.
 1859. † Waugh, Edwin. Sager-street, Manchester.
 * Way, J. Thomas, F.C.S., Professor of Chemistry, Royal Agricultural
 Society of England. 15 Welbeck-street, Cavendish-square,
 London.
 Webb, Rev. John, M.A., F.S.A. Hardwick Parsonage, Hay, South
 Wales.
 * Webb, Rev. Thomas William, M.A., F.R.A.S. Hardwick Parsonage,
 Hay, South Wales.
 1856. † Webster, James. Hatherley Court, Cheltenham.
 1859. † Webster, John. 42 King-street, Aberdeen.
 1858. † Webster, John. Broomhall Park; and St. James's-row, Sheffield.
 1862. † Webster, John Henry, M.D. Northampton.
 1864. § Webster, John. Sneinton, Nottingham.
 Webster, Thomas, M.A., F.R.S. 2 Great George-street, Westminster.
 1853. † Weddell, Thomas. Scarborough.
 1845. † Wedgewood, Hensleigh. 17 Cumberland-terrace, Regent's Park,
 London.
 1854. † Weightinan, William Henry. Litherland, Liverpool.
 1865. § Welch, Christopher. University Club, Pall Mall East, London.
 1850. † *Welsh, John.*
 1850. † Wemyss, Alexander Watson, M.D. St. Andrews.
 1850. † Wemyss, William. 6 Salisbury-road, Edinburgh.
 Wentworth, Frederick W. T. Vernon. Wentworth Castle, near
 Barnsley, Yorkshire.
 1864. * Were, Anthony Berwick. Wigton, Cumberland.
 1865. § Wesley, William Henry. 31 Clayland-road, Clapham, London.
 1853. † West, Alfred. Holderness-road, Hull.
 1858. † West, F. H. Chapel Allerton, near Leeds.
 1853. † West, Leonard. Summergangs Cottage, Hull.
 1853. † West, Stephen. Hessle Grange, near Hull.
 Westcott, Jasper.
 1851. † Western, Thomas Burch. Tattingstone House, Ipswich.
 1851. * Western, Sir T. B., Bart., M.P. Felix Hall, Kelvedon, Essex.
 1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
 Westhead, John. Manchester.
 1842. * Westhead, Joshua Proctor. York House, Manchester.

Year of
Election.

1851. † Westhorpe, Stirling. Tower-street, Ipswich.
 1857. * Westley, William. 24 Regent-street, London.
 1863. † Westmacott, Percy. Wickham, Gateshead, Durham.
 1860. § Weston, James Woods. Seedley House, Pendleton, Manchester.
 1858. † *Weston, William. Birkenhead.*
 1864. § Westropp, W. H. S., F.R.G.S.I. 2 Idrone-terrace, Blackrock, Dublin.
 1860. † Westwood, John O., M.A., F.L.S. Henley House, Summertown, Oxon.
 Wharton, W. L., M.A. Dryburn, Durham.
 1849. † Wheateley, George. Birmingham.
 1853. † Wheatley, E. B. Cote Wall, Merfield, Yorkshire.
 Wheatstone, Charles, D.C.L., F.R.S., Hon. M.R.I.A., Professor of Experimental Philosophy in King's College, London. 19 Park-crescent, Regent's Park, London.
 1847. † Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London.
 1853. † Whitaker, Charles J. P. Milton Hill, near Hull.
 1859. * Whitaker, William, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London.
 1864. § White, Edmund. New Bond-street, Bath.
 White, John. 80 Wilson-street, Glasgow.
 1859. † White, John Forbes. 16 Bon Accord-square, Aberdeen.
 1865. § White, Joseph. Regent's-street, Nottingham.
 1859. † White, Thomas Henry. Tandragee, Ireland.
 1861. † Whitehead, James, M.D. 87 Mosley-street, Manchester.
 1854. † Whitehead, James W. 15 Duke-street, Edge-hill, Liverpool.
 1858. † Whitehead, J. H. Southsyde, Saddleworth.
 1861. * Whitehead, J. B. Oakley-terrace, Rawtenstall, Manchester.
 1861. * Whitehead, Peter Ormerod. Belmont, Rawtenstall, Manchester.
 1855. * *Whitehouse, Wildman. Bexley-place, Greenwich, Kent.*
 Whitehouse, William.
 * Whiteside, James, M.A., Q.C., M.P. 2 Mountjoy-square, Dublin.
 Whiteside, Rev. J. W., LL.D. Vicarage, Scarborough, Yorkshire.
 1861. † Whitford, J. Grecian-terrace, Harrington, Cumberland.
 1852. † Whitla, Valentine. Beneden, Belfast.
 Whitley, Rev. Charles Thomas, M.A., F.R.A.S., Reader in Natural Philosophy in the University of Durham. Bedlington, Morpeth.
 1865. § Whittern, James Sibley. Wyken Colliery, Coventry.
 1857. * Whitty, John Irwine, M.A., D.C.L., LL.D., Civil Engineer. Ricketstown Hall, Carlow.
 1863. * Whitwell, Thomas. Stockton-on-Tees.
 * Whitworth, Joseph, LL.D., F.R.S. The Firs, Manchester; and Stancliffe Hall, Derbyshire.
 1857. † Widdup, —. Penzance; and Kilburn, Co. Wexford.
 1865. § Wiggin, Henry. Metchley Grange, Harbourn, Birmingham.
 1863. † *Wigham, John. Dublin.*
 1852. † Wigham, Robert. Norwich.
 1854. § Wight, Robert, M.D., F.R.S., F.L.S. Grazeley Lodge, Reading.
 1860. † Wilde, Henry. 2 St. Ann's-place, Manchester.
 1852. † *Wilde, William R.*
 Wilderspin, Samuel. Wakefield.
 1855. † Wilkie, John. 46 George-square, Glasgow.
 1861. * Wilkinson, Eason, M.D. Greenheys, Manchester.
 1857. † Wilkinson, George. Monkstown, Ireland.
 1859. § Wilkinson, Robert. Totteridge Park, Herts.
 Willan, William.
 * Willert, Paul Ferdinand. Manchester.
 1859. † Willet, John, C.E. 35 Albryn-place, Aberdeen.

Year of
Election.

- *Williams, Caleb, M.D. Micklegate, York.
Williams, Charles James B., M.D., F.R.S., Professor of Medicine in University College, London. 49 Upper Brook-street, Grosvenor-square, London.
1861. *Williams, Charles Theodore, B.A. 40 Upper Brook-street, London
Williams, Charles Wye. City of Dublin Steam Packet Company Water-street, Liverpool.
1864. *Williams, Frederick M., M.P., F.G.S. Goonvrea, Perranarworthal, Cornwall.
1861. *Williams, Harry Samuel. 49 Upper Brook-street, Grosvenor-square, London.
1857. †Williams, Rev. James. Llanfairinghornwy, Holyhead.
Williams, Richard. 38 Dame-street, Dublin.
Williams, Robert, M.A. Bridehead, Dorset.
1861. †Williams, R. Price. 22 Ardwick Green, Manchester.
Williams, Walter. St. Alban's House, Edgbaston, Birmingham.
1854. †Williams, William.
*Williams, William. Highbury-crescent, London.
1865. §Williams, William M. The Celyn, Caergwele, near Wrexham.
1850. *Williamson, Alexander William, Ph.D., F.R.S., F.C.S., Professor of Chemistry, and of Practical Chemistry, University College, London. 16 Provost-road, Haverstock-hill, London.
1857. †Williamson, Benjamin. Trinity College, Dublin.
1863. †Williamson, John. South Shields.
*Williamson, Rev. William, B.D. Datchworth, Welwyn, Hertfordshire.
Williamson, W. C. Manchester.
Willis, Rev. Robert, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 23 York-terrace, Regent's Park, London; and Cambridge.
1865. *Willmott, Henry. Mona House, Handsworth, Birmingham.
1857. †Willock, Rev. W. N., D.D. Cleenish, Enniskillen, Ireland.
1859. *Wills, Alfred. 4 Harcourt-buildings, Inner Temple, London.
1865. §Wills, Arthur W. Edgbaston, Birmingham.
1864. †Wills, W. D. Portland-square, Bristol.
Wills, W. R. Edgbaston, Birmingham.
*Wilson, Alexander, F.R.S. 34 Bryanston-square, London.
1859. §Wilson, Alexander Stephen, C.E. North Kinnmudy, Summerhill, by Aberdeen.
1850. †Wilson, Dr. Daniel. Toronto, Upper Canada.
1863. †Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, F. Dallam Tower, Milnethorp, Westmoreland.
1863. §Wilson, George. Hawick.
1861. †Wilson, George Daniel. 24 Ardwick Green, Manchester.
1855. †Wilson, Hugh. 75 Glassford-street, Glasgow.
1847. †Wilson, James Hewetson. The Grange, Worth, Sussex.
1857. †Wilson, James Moncrieff. 9 College Green, Dublin.
1858. *Wilson, John. Seacroft, near Leeds.
*Wilson, John. Bootham, York.
1855. *Wilson, John, jun. West Hurlet, near Glasgow.
1865. §Wilson, J. M., M.A. Rugby.
Wilson, Professor John, F.G.S., F.R.S.E. Museum, Jermyn-street, London.
1847. *Wilson, Rev. Sumner. Horton Heath, Bishopstoke.
*Wilson, Thomas, M.A. Crimbles House, Leeds.
1859. †Wilson, Thomas. Tunbridge Wells.
1863. *Wilson, Thomas. Shotley Hall, Gateshead, Durham.
1861. †Wilson, Thomas Bright. 24 Ardwick Green, Manchester.

Year of
Election.

1847. *Wilson, William Parkinson, M.A., Professor of Pure and Applied Mathematics in the University of Melbourne.
1861. §Wiltshire, Rev. Thomas, M.A., F.G.S., F.R.A.S. Rectory, Breadstreet-hill, London.
1846. †Winchester, The Marquis of. Amport House, Andover.
1855. †Wingate, Major H. Bendarnoch, Glasgow.
- *Winsor, F. A. 60 Lincoln's Inn Fields, London.
1854. †Winter, Thomas.
1863. *Winwood, Rev. H. H., M.A., F.G.S. 4 Cavendish-crescent, Bath.
1848. †Wise, Rev. Stainton, M.D. Banbury.
1856. †Witts, Rev. E. F. Upper Slaughter, Cheltenham.
- *Wollaston, Thomas Vernon, M.A., F.L.S. Barnpark-terrace, Teignmouth.
1850. †Wood, Alexander, F.R.C.P. Edinburgh.
1863. §Wood, C. L. Howlish Hall, Bishop Auckland.
1863. †Wood, Edward, F.G.S. Richmond, Yorkshire.
1861. *Wood, Edward T. Brinseall Hall, Chorley, Lancashire.
1860. †Wood, George, M.A. Bradford, Yorkshire.
1861. *Wood, George B., M.D. Philadelphia, United States.
1856. *Wood, Rev. H. H., M.A., F.G.S. Holwell Rectory, Sherborne, Dorset.
- *Wood, John. St. Saviour Gate, York.
- Wood, Peter, M.D.
1864. §Wood, Richard, M.D. Driffield, Yorkshire.
1861. §Wood, Samuel, F.S.A., F.G.S. St. Mary's Court, Shrewsbury.
1850. †Wood, Rev. Walter. Elie, Fife.
- Wood, William. 1 Harrington-street, Liverpool.
1858. *Wood, William. Monkhill House, Pontefract.
1865. §Wood, William, M.D. 54 Upper Harley-street, London.
1861. †Wood, William Rayner. Singleton Lodge, near Manchester.
- *Wood, Rev. William Spicer, M.A. Oakham, Rutlandshire.
1863. *Woodall, Major John Woodall, M.A., F.G.S. St. Nicholas House, Scarborough.
1850. *Woodd, Charles H. L., F.G.S. Roslyn, Hampstead, London.
- *Woodhead, G. Mottram, near Manchester.
1865. §Woodhill, J. C. Pakenham House, Edgbaston, Birmingham.
- *Woods, Edward. 5 Gloucester-crescent, Hyde Park, London.
- Woods, Samuel. 3 Copthall Buildings, Angel-court, London.
- Woolgar, J. W., F.R.A.S. Lewes, Sussex.
- Woolley, John. Staleybridge, Manchester.
1857. †Woolley, Rev. J., LL.D. Her Majesty's Dockyard, Portsmouth.
1856. §Woolley, Thomas Smith, jun. South Collingham, Newark.
1853. †Worden, John.
- *Wormald, Richard. 6 Brondesbury-terrace, Kilburn, London.
1863. *Worsley, P. John. Codrington-place, Clifton, Bristol.
1849. †Worsley, Samuel. Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Mansfield.
- Worthington, Archibald. Whitechurch, Salop.
- Worthington, James. Polygon, Ardwick, Manchester.
1842. *Worthington, Robert. Ardwick, Manchester.
- Worthington, William. Brockhurst Hall, Northwich, Cheshire.
1856. §Worthy, George S. 130 Vine-street, Liverpool.
- Wray, John. 6 Suffolk-place, Pall Mall, London.
1857. †Wright, Edward. 43 Dame-street, Dublin.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.
1857. §Wright, E. Perceval, A.M., M.D., F.L.S., M.R.I.A., Lecturer on Zoology, and Director of the Museum, Dublin University. 10 Clare-street, Dublin.

Year of
Election.

1858. †Wright, Henry. Stafford House, London.
 Wright, John.
 Wright, J. Robinson, C.E. 11 Duke-street, Westminster.
1865. §Wright, J. S. 168 Brearley-street West, Birmingham.
 *Wright, Robert Francis. Hinton Blewett, Somersetshire.
1855. §Wright, Thomas, F.S.A. 14 Sydney-street, Brompton, London.
 Wright, T. G., M.D. Wakefield.
1865. §Wrightson, Francis, Ph.D. Ivy House, Kingsnorton.
 Wrottesley, John, Lord, M.A., D.C.L., F.R.S., F.R.A.S. Wrottesley
 Hall, Wolverhampton.
 Wyld, James, M.P., F.R.G.S. Charing Cross, London.
1863. *Wyley, Andrew. Drumadarragh, Doagh, Belfast.
1845. †Wylie, John, M.D. *Madras Army.*
1862. †Wynne, Arthur Beevor, F.G.S., of the Geological Survey of Ireland.
 Sligo, Ireland.
- *Yarborough, George Cook. Camp's Mount, Doncaster.
1857. †Yates, Edward. 30 Compton-terrace, Islington, London.
1865. §Yates, Edwin. Burton-upon-Trent.
1865. §Yates, Henry. Emscote Villa, Aston Manor, Birmingham.
 Yates, James. Carr House, Rotherham, Yorkshire.
 Yates, James, M.A., F.R.S., F.G.S., F.L.S. Lauderdale House, High-
 gate, London.
1845. †Yates, John Aston. 53 Bryanston-square, London.
1855. †Yeats, John, LL.D., F.R.G.S. Leicester House, Peckham, London.
 *Yorke, Colonel Philip, F.R.S., F.R.G.S. 89 Eaton-place, Belgrave-
 square, London.
 Young, James. South Shields.
 Young, James. Limefield, West Calden, Midlothian.
 Young, John. Taunton, Somersetshire.
1858. †Young, John. Hope Villa, Woodhouse-lane, Leeds.
 Young, Thomas. North Shields.
 Younge, Robert, F.L.S. Greystones, near Sheffield.
 *Younge, Robert, M.D. Greystones, near Sheffield.
1865. §Younghusband, Major-General. Ellom House, Charlton-road, Chel-
 tenham.
1854. †Zwilchenburt, Emanuel. 3 Romford-street, Liverpool.

CORRESPONDING MEMBERS.

Year of
Election.

1857. M. Antoine d'Abbadie.
Louis Agassiz, M.D., Ph.D., Professor of Natural History. Cambridge,
U.S.
1852. M. Babinet. Paris.
Dr. Alexander Dallas Bache. Washington, U. S.
1857. Dr. Barth.
1866. Captain I. Belavenetz, R.I.N., F.R.I.G.S., M.S.C.M.A., Superin-
tendent of the Compass Observatory, Cronstadt, Russia.
1861. Dr. Bergsma, Director of the Magnetic Survey of the Indian Archi-
pelago. Utrecht, Holland.
1857. Professor Dr. T. Bolzani. Kasan, Russia.
1852. Mr. G. P. Bond. Observatory, Cambridge, U.S.
1846. M. Boutigny (d'Evreux).
1842. Professor Braschman. Moscow.
1864. Dr. H. D. Buys-Ballot, Superintendent of the Royal Meteorological
Institute of the Netherlands. Utrecht, Holland.
1861. Dr. Carus. Leipzig.
1864. M. Des Cloizeaux. Paris.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1866. Geheimrath von Dechen. Bonn.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidel-
berg.
1845. Heinrich Dove, Professor of Natural Philosophy in the University of
Berlin.
Professor Dumas. Paris.
Professor Christian Gottfried Ehrenberg, M.D., Secretary of the Royal
Academy, Berlin.
1846. Dr. Eisenlohr. Carlsruhe, Baden.
Professor Johann Franz Encke. Berlin.
1842. Dr. A. Erman. Berlin.
1848. Professor Esmark. Christiania.
1861. Professor A. Favre. Geneva.
1855. M. Léon Foucault. Paris.
1856. Professor E. Frémy. Paris.
1842. M. Frisiani. Milan.
1866. Dr. Gaudry, Pres. Geol. Soc. of France. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1852. Professor Asa Gray. Cambridge, U.S.
1866. Professor Edward Grube, Ph.D.
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences,
Amsterdam. Leiden, Holland.
Professor Henry. Washington, U.S.
1864. Professor E. Hébert. The Sorbonne, Paris.
1861. Dr. Hochstetter. Vienna.
1848. Dr. Van der Hoeven. Leyden.
1842. M. Jacobi. St. Petersburg.
1862. Charles Jessen, Med. et Phil. Dr., Professor of Botany in the Univer-
sity of Greifswald, and Lecturer of Natural History, and Librarian
at the Royal Agricultural Academy, Eldena, Prussia.

Year of
Election.

1866. Dr. Henry Kiepert, Professor of Geography. Berlin.
 1862. Aug. Kekulé, Professor of Chemistry. Ghent, Belgium.
 1861. M. Khanikof. 97 Rue de Lille, Paris.
 1856. Professor A. Kölliker. Würzburg, Bavaria.
 1856. Laurent-Guillaume De Koninck, M.D., Professor of Chemistry and
 Palæontology in the University of Liège, Belgium.
 1845. Dr. A. Kupffer. St. Petersburg.
 Dr. Lamont. Munich.
 Baron von Liebig. Munich.
 1862. Professor A. Escher von der Linth. Zurich, Switzerland.
 1857. Professor Loomis. New York.
 1850. Professor Gustav Magnus. Berlin.
 1847. Professor Matteucci. Pisa, Tuscany.
 1862. Professor P. Merian. Bâle, Switzerland.
 1846. Professor von Middendorff. St. Petersburg.
 1848. Dr. J. Milne-Edwards. Paris.
 1855. M. l'Abbé Moigno. Paris.
 1864. Dr. Arnold Moritz. Tiflis, Russia.
 1856. W. Morren, Professeur de Botanique à l'Université de Liège, Belgium.
 1866. Chevalier C. Negri. Florence, Italy.
 1864. Herr Neumayer. Munich.
 1848. Professor Nilsson. Sweden.
 1852. Dr. N. Nordenskiöld. Frugard, near Helingfors, Russia.
 1856. M. E. Peligot, Memb. de l'Institut, Paris.
 1861. Professor Benjamin Pierce. Cambridge, U.S.
 1857. Gustav Plaar. Strasburg, France.
 1849. Professor Plücker. Bonn, Prussia.
 1852. M. Constant Prévost. Paris.
 M. Quetelet. Brussels.
 M. De la Rive. Geneva.
 1866. Dr. F. Römer, Professor of Geology. Berlin.
 1850. Professor W. B. Rogers. Boston, U.S.
 1857. Herman Schlagintweit. Berlin.
 1857. Robert Schlagintweit. Berlin.
 1861. M. Werner Siemens. Berlin.
 1849. Dr. Siljeström. Stockholm.
 1862. J. A. de Souza, Professor of Physics in the University of Coimbra,
 Portugal.
 1864. Adolph Steen, Professor of Mathematics, Copenhagen.
 1866. Professor Steenstrup. Copenhagen.
 1845. Dr. Svanberg. Stockholm.
 1852. M. Pierre Tchihatchef.
 1864. Dr. Otto Torell. University of Lund, Sweden.
 1864. Professor A. Vambery. Hungary.
 1861. Professor E. Verdet. Paris.
 1861. M. de Verneuil, Memb. de l'Institut, Paris.
 1848. M. Le Verrier. Paris.
 Baron Sartorius von Waltershausen. Göttingen, Hanover.
 1842. Professor Wartmann. Geneva.
 1864. Dr. Frederick Welwitsch. Lisbon.

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